

**“A STUDY ON THE EFFECT OF PROTECTION ON  
REGENERATION STATUS, SPECIES DIVERSITY,  
STRUCTURE AND BIOMASS PATTERN OF THREE SITES  
OF TROPICAL DECIDUOUS FOREST”**

**M.Sc. (Forestry) THESIS**

**BY**

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**Thesis**

**Submitted to the**

**INDIRA GANDHI KRISHI VISHWAVIDYALAYA  
RAIPUR**

**BY**

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## **CERTIFICATE – I**

This is to certify that the thesis entitled “**A STUDY ON THE EFFECT OF PROTECTION ON REGENERATION STATUS, SPECIES DIVERSITY, STRUCTURE AND BIOMASS PATTERN OF THREE SITES OF TROPICAL DECIDUOUS FOREST**” submitted in partial fulfilment of the requirements for the degree of “**MASTER OF SCIENCE IN FORESTRY**” of Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **PAWAR GEETA VISHAL** under my guidance and supervision. The subject of the thesis has been approved by Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date:

**(Lalji Singh)**  
**Chairman**  
Advisory Committee

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## **CERTIFICATE – II**

This is to certify that the thesis entitled “**A STUDY ON THE EFFECT OF PROTECTION ON REGENERATION STATUS, SPECIES DIVERSITY, STRUCTURE AND BIOMASS PATTERN OF THREE SITES OF TROPICAL DECIDUOUS FOREST**” submitted by **PAWAR GEETA VISHAL** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfilment of the requirement for the degree of M.Sc. in the Department of Forestry has been approved by external examiner and Student’s Advisory Committee after oral examination.

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## LIST OF ABBREVIATIONS

Abbreviations	Description
%	Percent
&	And
<	Less Than
=	equal to
>	More Than
≤	less than equal to
≥	greater than equal to
°C	degree centigrade
AGB	Above ground biomass
AGBD	Above ground biomass density
C.G.	Chhattisgarh
CBH	Circumference at breast height
cm	centimeter
cm <sup>2</sup>	centimeter square
DBH	Diameter at breast height
<i>et al</i>	And others/co-workers
Fig.	Figure
FSI	Forest Survey of India
GBH	Girth at Breast Height
GIS	Geographical Information System
GOI	Government of India
ha	hectare
ha <sup>-1</sup>	per hectare
i.e.	that is
Ind	Individual
IVI	Importance Value Index
Kg/tree	kilogram per tree

Abbreviations	Description
Kg ha <sup>-1</sup>	kilogram per hectare
Km	kilometer
m	meter
m <sup>2</sup>	meter square
MAB	Man and Biosphere
Mg	mega gram = 10 <sup>6</sup> gram
Mgha <sup>-1</sup>	mega gram per hectare
Mgha <sup>-1</sup> yr <sup>-1</sup>	mega gram per hectare per year
MoEF	Ministry of Environment and Forest
NE	North East
NPP	Net Primary Productivity
R.B.A.	Relative Basal Area
R.D.	Relative Density
R.F.	Relative Frequency
TAGB	Total above ground dry biomass
TDF	Tropical Deciduous Forest
t ha <sup>-1</sup>	tons per hectare
t ha <sup>-1</sup> yr <sup>-1</sup>	tons per hectare per year
UNEP	United Nation Environment Programme
viz.	namely

## *INTRODUCTION*

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## CHAPTER-I

### INTRODUCTION

Tropical forests play crucial roles in the functioning of our planet and the maintenance of life (Myers, 1996). Covering only 7% of the earth's land surface the tropical forests have more than half of the world's species (May & Stump, 2000), serve as regulators of global and regional climate systems (Gedney & Valdes, 2000), act as carbon sinks (Grace *et al.*, 1995), provide valuable ecosystem services and serve as vital resources for human populations (Laurance, 1999). Tropical forests in India cover 56.60 m ha of total geographical area of the country which comes out to be 81.96 % of the actual forest covers of which nearly one third (33.92%) falls in the tropical moist deciduous type and 30.16% falls under dry deciduous forest (FSI, 2009). Tropical forests often referred to as one of the most species diverse terrestrial ecosystems (Kumar *et al.*, 2006) and most used and threatened ecosystems, especially in India (Shankar, 2001) which contributes around 69% of earth's biological productivity, due to the high rate of carbon and nutrient turnover in soil.

Tropical deciduous forests occur under varied climatic conditions, but essentially with alternate wet and dry period. However, the structure, composition and functioning of deciduous forests undergo changes with the length of wet period, amount of rainfall, latitude, longitude and altitude (Shankar, 2001) and impacts of human and livestock activities. Tropical forests harbour the greatest wealth of biological and genetic diversity on the earth. These biodiversity rich forests have world attention because of the growing awareness of its importance on the one hand and the anticipated massive depletion on the other (Singh, 2002).

Tropical forests are disappearing at alarming rate of 0.8-2.0% per year (May & Stump, 2000) due to extraction of timber and other forest produce ( Raghubanshi & Tripathi, 2009) and it is argued that continuing biomass extraction activities may thwart the very goal of biodiversity conservation (Schaik *et al.*, 1997). In India, habitat destruction, overexploitation, pollution and species introduction are identified as a major cause of diversity loss (UNEP, 2001). In most developing countries, including India, even protected forests experience extensive anthropogenic disturbance (Singh *et al.*, 1997). The degree of anthropogenic disturbance may differ in different parts of a conservation area (Kolongo *et al.*, 2006). These human induced impacts have caused a significant loss to biodiversity especially in regions which are under the process of development (Mishra *et al.*, 2008).

Forest disturbance can alter environmental conditions by changing light availability and soil conditions (Fredericksen and Mostacedo, 2000), also influences processes that can either augment or erode the ecological functions of a forest community (Sagar *et al.*, 2003). Both natural and human disturbances influence forest dynamics and tree diversity at local and regional scales (Hong *et al.*, 1995; Hubbell *et al.*, 1999; Sheil, 1999; Ramirez-Marcial *et al.*, 2001). An increasing interest in the development and management of natural forests has given rise to the need to understand the community structure and ecosystem stability (Anitha *et al.*, 2007).

The unabated degradation of forests in India has caused the forest cover to decline by 728 km<sup>2</sup> in India of which 59 km<sup>2</sup> decline in Chhattisgarh, there is severe ongoing anthropogenic pressure on the remaining forests which will probably result in further loss unless protection/conservation measures are undertaken. Even if the target of 10–12%

land protected and reserved across the globe is achieved, up to 50% of tropical species are predicted to go extinct in the next few decades (Soule and Sanjayan, 1998). While the first priority for conservation is still increasing the number of protected areas globally, it is also important to address issues related to sustainable forest management outside protected areas (Putz *et al.*, 2001).

India has 2.5 per cent of the world's land area and 1.8 per cent of the global forest area which supports 15.6 per cent of the world's human population and 14 per cent of the livestock population. This large population depends on forest for the supply of fuel wood, raw materials for rural handicrafts and industries, among other products. However in India, the forest cover is 21.02 per cent of the geographical area and much of it is under anthropogenic stress (FSI, 2009). About 14-40 thousand species per year are estimated to be lost due to tropical forest habitat destruction (Hughes *et al.*, 1997). Approximately 492 genetically distinct population of trees are endangered globally (NRC [National Research Council] 1991) and some species have been reduced to a single specimen in many countries due to habitat loss.

In areas influenced by humans, many species have been purged (Chapin III *et al.*, 2000). Factors, such as, the available pool of species, the physical characteristics of the land, soil fertility, climate and disturbance regime characteristics, control the vegetation dynamics of forests system (Gauthier *et al.*, 2000). Understanding and managing the disturbance regimes of a landscape under past natural or semi-natural conditions is one of the foundations of conservation of biodiversity in forest landscapes (Spies and Turner, 1999). This more subtle process of forest degradation refers to the temporary or

permanent decrease in the density, biomass and/or overall structure of vegetation cover and/or its species composition (Grainger, 1993; Sgrenzaroli *et al.*, 2002).

India has lost about 7% of its dense forests (with canopy cover of 40% or more) in just two years between 2001 and 2003. The per capita availability of forestland had declined steadily from 1.2 ha in 1951 to a meager 0.0747 ha in 2001, as against 0.2 ha in Asia-Pacific region (Sen *et al.*, 2008). The destruction of the world's tropical forests, which are disappearing at an alarming rate, is one of today's most urgent global environment issues. The fragmented and reduced populations that result from human disturbance are issues of growing importance in evolutionary and conservation biology (Sork *et al.*, 2002).

Much attention has been given to tropical forests due to their species richness (Whitmore, 1984), high standing biomass (Bruenig, 1983) and greater productivity (Jordan, 1983) and therefore it is liable to overexploitation. However, many of these forests are losing this ability due to excessive biotic interference and this process of deforestation has been contained over the years, pressures leading to erosion of forest biomass and local extinctions of species continue (Daniels *et al.*, 1995). Kharkwal *et al.* (2005) opine that accelerated species loss could lead to collapse of the ecosystem. Any form of disturbance whether natural or anthropogenic tends to change the forest structure, dynamics and composition. Disturbance of ecosystem has implications for the maintenance and restoration of biodiversity at all hierarchical levels (McNaughton, 1989; Walker, 1989; Pickelt and Parker, 1994).

The changes in forest ecosystems are considered to have global conservation importance since the effects of significant forest-cover loss or within forest modification

may include massive soil erosion (Sidle *et al.*, 2006), destabilization of watersheds (Rai and Sharma, 1998), a loss of sustainable forest uses, threats to indigenous people on a regional scale (Samal *et al.*, 2003) and large scale release of atmospheric carbon dioxide. A thorough understanding of the dynamics of the forests can help to increase the productivity, to maintain species composition, to limit financial inputs and to develop prescription for silvicultural operations (Oliver and Larson, 1996; Bhat *et al.*, 2000) and also to conserve the plant diversity (Murali *et al.*, 1996). The conservation and improvement of forest utilization have increased the interest in studies addressing the structure and function of forest ecosystems mainly the soil properties (Gallego *et al.*, 1993).

Species diversity is an important concept and one of the major attributes of a natural community. Floristic inventory and diversity studies help us to understand the species composition and diversity status of forests and offer vital information for forest conservation (Gordon and Newton, 2006). Studies have shown that composition and structure of forest are influenced by a number of factors (Haugassen *et al.*, 2003). Prominent among these factors are disturbances which are thought to be key aspects and the cause of local species variation within forests based on their intensity, scale and frequency (Hill and Curran, 2001; Laidlaw *et al.*, 2007).

The Tropical forests play an important role in biomass accumulation and in global C cycle both in terms of C flux and the volume of C stored. Disturbance can alter the successional pattern, subsequent diversity and biomass of forest. Biomass estimation is needed for understanding the structure and dynamic functions of an ecosystem (Ovington, 1962) and for comparing the status and trends of forest ecosystems across a

wide range of environmental conditions. Understanding the patterns of storage and production of organic matter in forests in relation to the disturbances is critical for management purposes. Above-ground biomass (AGB) is a useful measure for assessing changes in forest structure (Brown *et al.*, 1999) and an essential aspect of studies of carbon cycle (Cairns *et al.*, 2003; Keller *et al.*, 2001; Ketterings *et al.*, 2001) which can also be used to understand changes in forest structure resulting from succession or to differentiate between forest types (Cairns *et al.*, 2003). Litterfall is the major pathway for the return of organic matter and nutrients from aerial parts of the plant community to the soil surface and fertility (Kumar and Ram, 2005). In tropical ecosystem maintenance of soil organic pool is achieved by the high and rapid circulation of nutrient. Dry matter accumulation and productivity of forests are influenced by the presence of nutrients in soils and their recycling.

However, there is severe ongoing anthropogenic pressure on the tropical forests, which calls for sustainable forestry to reduce poverty, integrating forests into sustainable economic development and protecting local and global forest values. Understanding vegetation changes following the disturbances caused by different factors is essential for developing management practices involving natural regeneration and to maintain the overall biodiversity, productivity and sustainability. Understanding the diversity of nature in various forms is a fundamental goal of ecological research (Lubchenco *et al.*, 1991). The structural and functional processes have to be quantified for thoroughly understanding the vegetation dynamics. On the other hand, woody biomass is also necessary for determining the status and flux of biological materials in an ecosystem (Anderson, 1970).

In view of this the present study entitled “A Study on the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest” was conducted to document changes in regeneration, diversity, structure and biomass of forest at relatively least, moderate and highly disturbed site in relation to human induced disturbance and protection/conservation status. The study was carried out with the following major objectives:-

1. To quantify the effect of protection on regeneration status.
2. To quantify the effect of protection on species diversity and species structure.
3. To quantify the effect of protection on biomass pattern.

## *REVIEW OF LITERATURE*

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## CHAPTER-II

### REVIEW OF LITERATURE

In this chapter an attempt has been made to review the work done on “**A Study on the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest**”. However, due to paucity of literature on few aspects, the similar types of studies carried in other forest ecosystems are also cited. The literature is broadly reviewed under the following major aspects.

#### **2.1 Regeneration status**

#### **2.2 Species diversity and structure**

#### **2.3 Biomass pattern**

#### **2.1 Regeneration status**

The study of regeneration of forest trees has important implications for the management of natural forests and is one of the thrust areas of forestry. Understanding of natural regeneration processes and the distribution of recruits is of paramount importance to examine the build-up of future forest structure and composition (Ceccon *et al.*, 2006). Forest resources are renewable only because they can regenerate. The regeneration dynamics or pace, at which older trees of a forest are replaced by younger ones in time and space, is determined by the regeneration potential of the component tree species and the factors that influence the actual regeneration.

Regeneration of any species is confined to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution

(Grubb, 1977). The population structure, characterized by the presence of sufficient population of seedlings, saplings and adults, indicates successful regeneration of forest species and presence of saplings under the canopies of adult trees also indicates the future composition of a community (Austin, 1977). Regeneration of a particular species is poor if seedlings and saplings are much less than the mature trees (Khan *et al.*, 1987; Tripathi and Khan, 2007).

Regeneration assessment is an important part of evaluation of forest status. Density of trees and their regeneration in the forest are largely dependent on the response of the seedling and saplings to the forest microenvironment and interactive influence of an array of biotic and abiotic factors (Shankar, 2001; Mishra *et al.*, 2003). Tree regeneration can be predicted by the structure of their populations (Khan *et al.*, 1987). A sustained regeneration and growth of all species in the presence of older plants is required for the growth of any plant community (Taylor and Zisheng, 1988). The presence of sufficient numbers of seedlings, saplings and young trees in a given population indicates successful regeneration (Khan *et al.*, 1987).

Regeneration status of trees can be predicted by the age structure of their population. Patterns of forest regeneration following natural or anthropogenic disturbances are also influenced by interactions between disturbance regimes (intensity, frequency, scale) and biological features of species. In addition intra and inter-specific competition for water, nutrients and space are also important factors in regeneration and growth of species (Dembele *et al.*, 2006).

Alelign *et al.* (2007) studied regeneration status and diversity of woody plants on the peninsula of Zegie, northwestern Ethiopia and found the occurrence of 240 coppiced

stumps, 91 dead stumps, nine stems with cut part left and one dead but standing stem which demonstrates that how the forest is heavily exploited. The fact that very few mature trees are left in the forest might also suggest reduced seed production that could jeopardize future regeneration of trees and therefore the welfare and even existence of the forest as a whole.

Anitha *et al.* (2007) investigated the effect of anthropogenic disturbances on tree community structure and their regeneration and stated that regeneration was affected badly in all the three stands (undisturbed, moderately disturbed and highly disturbed) of the area due to anthropogenic disturbances like lopping, cattle grazing and collection of non-wood forest products.

Ceccon *et al.* (2006) have analyzed the effect of abiotic factor on tropical dry forests (TDF) regeneration and stated that abiotic factors have significant impact on the natural dynamics of TDF regeneration and their conservation.

Chauhan *et al.* (2008) compared regeneration, tree diversity and floristic diversity of natural and planted tropical deciduous forests. In both sites 126 species were found, of which 32.5% showed good regeneration, 19.8% fair, 24.6% poor and 11.1% lacked regeneration. The remaining 11.9% of species were present as seedlings but not as adult individuals. Good quality timber species were not regenerating although mortality at seedling stage of this species was high.

Eilu and Obua (2005) have studied the tree condition and natural regeneration in disturbed sites of Bwindi Impenetrable Forest National Park, south-western Uganda and stated that high intensity human disturbance adversely affected tree species abundance, diversity and regeneration whereas also increased the incidence of damage to trees and

found higher stem densities in undisturbed and lightly disturbed forest types compared to heavily or completely disturbed forest types and regeneration from vegetative sprouts was highest in disturbed sites while regeneration from seeds was highest in undisturbed sites. As noted by Webb (1998), logging gaps tend to return pre-logging composition with time under a carefully implemented and controlled harvesting regime. With the exception of the completely disturbed sites, the selectively logged sites approximate a controlled harvesting regime.

Gunasekara *et al.* (2001) enumerated the temporal vegetation changes in selectively logged and unlogged stands in Sinhareja forest reserve, Srilanka where the highest number (121-134 sp) of species was recorded in unlogged than (116-114 sp) in logged area. After 20 years 13 and 4 additional species were recorded in unlogged and logged areas, respectively.

Khurana (2007) has carried out analysis of tree layer and regeneration status of tropical dry deciduous forest along the disturbance gradient and concluded that biotic disturbances are making the site poor in nutrients and eroding top soil making the regeneration pattern inadequate.

Muhanguzi *et al.* (2005) have suggested that soil loosening can enhance emergence of seedlings of several tropical forest tree species of different successional status, most probably, because it exposes formerly buried seeds to incident radiation and improves soil aeration and drainage. They also stated that forest gaps seem to favour the emergence of tree seedlings of more diverse tree species than closed canopy habitats. In their study the emergence of seedlings of pioneer tree species were restricted to forest gaps and forest edges because their seeds need direct light for germination otherwise the

seeds of these species may stay dormant in the soil until such forest light condition prevail.

Pande (1999) studied the vegetation of Sal forest of Doon valley and relate the magnitude of disturbance with quantification of vegetation, their resource apportionment and the regeneration of Sal. The whole area was divided into five sites as per their disturbance magnitude. He noticed that not only disturbance and stand age affect the Sal regeneration due to invasion of new competitors at seedling and sampling stage but the compactness of stand due to old and big trees also reduce it by increasing moisture status of soil at the moist areas.

Sahoo *et al.* (2008) has assessed the phyto-sociology of *Pinus Kesiya* stands exposed to varying intensities of disturbance in North East India and suggested that the disturbance can lead to the formation of mixed forest and the mildly disturbed sites are the best for regeneration and more assemblage of plant species there by providing scope for proper silvicultural and management implications in the undisturbed forest stands to provide the growth of seedlings and saplings of the dominant species.

Shankar (2001) studied floristic composition, regeneration and conservation of sal dominated forest in Eastern Himalaya and found that diverse sal forest continually experiences anthropogenic interference by the inhabitants on fringes. Rare species that contribute maximum to the tree diversity are at high risk of local extinction. Thus of all 93 species, 20.4% showed good regeneration, 10.8% fair, 30.1% poor and 17.2% lacked regeneration. The remaining 21.5% species seem to be reappearing.

Singh (2002) has stated that most plans for conservation have focused on biodiversity, ignoring the importance of ecosystem services. Recent exercises on the

prioritization of creatures and places deserving most attention for conservation and on developing national biodiversity conservation plans in several Asian countries may further increase its imbalance.

## **2.2 Species Diversity and Structure**

Tree species diversity is an important aspect of forest ecosystem (Rennolls and Laumonier, 2000). Tree species inventories at defined sites and in minimum diameter classes give a reliable instrument to indicate the diversity level of a study site (Wattenberg and Breckle, 1995). The structural and functional processes have to be quantified for thoroughly understanding the vegetation dynamics. The structural analysis of vegetation entail the floristic composition, stand density, basal area, vertical stratification and community types, while diversity provides information on species richness, distribution and rate of change in species composition. Both structure and diversity of vegetation have strong functional role in controlling ecosystem process like biomass production, cycling of water and nutrients (Gower *et al.*, 1992). The strong correlation exists between structural diversity and species diversity (Sahu *et al.*, 2008).

Quantitative floristic sampling also provides the necessary context for planning and interpreting long-term ecological research (Phillips *et al.*, 2003). The long-term permanent plot and permanently tagged individuals of trees provide a unique opportunity to investigate the dynamics of individual species and total forest in space and time (Ayyappan and Parthasarathy, 2001). Such large-scale permanent plot studies are also important for conservation and management of tropical forests (Field and Vazquezynes, 1993). Recently the number of permanent plots has increased rapidly in various tropical

forests of the world (Hubbell and Foster, 1983; Manokaran *et al.*, 1990; Sukumar *et al.*, 1992; Condit, 1995; Aiba and Kitayama, 1999; Ayyappan and Parthasarathy, 2001; Nebel *et al.*, 2001; Sagar and Singh, 2003).

Plant diversity inventories in tropical forests have mostly been concentrated on tree species than the other life forms because tree species diversity is an important aspect of forest ecosystem diversity and also fundamental to total tropical forest biodiversity. They provide resources and habitat structure for almost all other species. Studies on tropical tree diversity have accumulated over the past decades and there is a great deal of interest to decipher the pattern and process relating to tropical forest diversity. Such diversity inventories are best integrated with the timber resources inventories in order that forest management operations can be planned (Rennolls and Laumonier, 2000).

Addo-Fordjour *et al.* (2009) studied the floristic composition, structure and natural regeneration in three plots each in undisturbed (UF), disturbed-invaded (DIF) and disturbed forest (DF) of the Tinte Bepo forest reserve. A total of 108 plant species belonging to 37 families, 77 genera and 8 life forms were identified in all the forest blocks. Species richness of all life forms was highest in the UF followed by the DIF and DF. Plant species diversity was quantitatively higher in the UF ( $H' = 3.6$ ) compared to the DIF ( $H' = 3.3$ ) and DF ( $H' = 2.9$ ). Plant species densities also differed significantly ( $P = 0.000$ ) among the forest types. Plant mean basal area, canopy cover and height were higher in the UF compared to the DF and DIF. There was a significant positive relationship between tree size and height in all the forest types studied.

Anitha *et al.* (2007) investigated the effect of anthropogenic disturbances on tree community structure and their regeneration in Anaikatty hills, Western Ghats and stated

that species richness varied according to the disturbance gradient in different stands. The undisturbed stand shows highest species richness (39 species) followed by moderately disturbed stand (23 species) and highly disturbed stand (21 species). The Shannon diversity index ranged from 2.09 to 3.06 in the three stands. The value of concentration of dominance also showed the same trend and it ranged from 0.73 to 0.9. The study revealed that higher level of disturbance altered diversity and other characteristics. Vegetation showed a trend of change from its original community structure.

Biswas (2007) has assessed the anthropogenic influence on the tropical evergreen Dipterocarp forests with a phyto-sociological perspective and recommended that management system with particular emphasis on participatory management, conservation of biodiversity and continuous community based monitoring is required to minimize the anthropogenic disturbances and restore the disturbed natural forest and sustainability of the existing forest. He further emphasized that lack of long term data analysis hinder the development of management scenarios for the sustainable management of the forest and continuous research incorporating the ecological, economic and human dimensions could help to develop such scenarios.

Chettri *et al.* (2006) analyzed the effect of anthropogenic pressures on the natural resources in the fringe areas of the Khangchendzonga Biosphere Reserve and found that population rise, family fragmentation and thereby increased pressures on these forests could affect the future composition of this Biosphere Reserve because resource use forms an integral part of buffer zone causing pressure and impact. In their study anthropogenic impact were more pronounced at lower elevations near the human settlements which needs the sustainable management of resources. They had suggested that judicious

management of the fringe area settlements in terms of village socioeconomy, resource needs and enhanced on-farm based resource production may reduce such type of pressures and stated that enhancement of local knowledge in conservation efforts could be the options for resolving future resource problems and emphasis on better livelihood options of local communities vis-à-vis legal protection of resources would help in minimizing anthropogenic pressures which may be achieved by both internal and external management of the Biosphere Reserve areas.

Devi and Behera (2003) have made a comparison between a relatively undisturbed dry deciduous forest and two degraded forests in the Badrama Reserve Forest of Bamra Division in Orrisa and found that the dominant tree species association in the undisturbed natural forest was *Shorea-Terminalia-Pterocarpus* which changed to *Shorea-Cleistanthus-Terminalia* and *Soymida-Semecarpus-Buchanania* in the disturbed forests. Diversity indices of tree, shrub and liana were maximum in the undisturbed natural forest and disturbance led to the decline in the diversity of these life forms. Disturbance in the natural forest led to the development of savannah with shrubby bushes and perennial grass species.

Joseph and Anitha (2008) have suggested a need for uniform hypothesis for disturbance, diversity and stability of ecological systems. Mohammed *et al.* (2008) have studied the floristic diversity of Ahobilan forest and suggested some of the conservational methods for implementation such as prevention on grazing, cultivation of forage crops, collection of wood/timber smuggling and formation of forest protection forces from tribal community which could reduce the anthropogenic pressure of the forest and enhance the protection of plant wealth.

Khurana and Saxena (2009) studied the vegetation and species diversity of tropical dry deciduous forest in Hastinapur, UttarPradesh along the disturbance gradient and found that natural competition; grazing, fire and deforestation are important causes of disturbances. Three sites were selected for vegetation study of tree and shrub layer i.e. Hillock, Block-1 and Block-2. Hillock was highly disturbed, while, Block-1 and Block-2 were moderately and least disturbed site, respectively. Total tree density varied from 8.52 stems  $100\text{ m}^{-2}$  to 9.9  $100\text{ stems m}^{-2}$ , while total seedling and sapling density varied between 2.0 stems  $100\text{ m}^{-2}$  to 7.0 stems  $100\text{ m}^{-2}$  and 5.35 stems  $100\text{ m}^{-2}$  and 6.90 stems  $100\text{ m}^{-2}$ , respectively. Density value increased with decreasing disturbance. Values of basal cover of trees, seedling and sapling were also increased with decreasing disturbance. Species richness for both tree and shrub layer decreased with decreasing disturbances. Species diversity decreased in similar fashion as species richness.

Krishnamurthy *et al.* (2010) have studied vegetation structure and floristic composition in a tropical dry deciduous forest of Bhadra wildlife sanctuary and concluded that plant density varied from 20- 90 individuals with an average of 35 individuals, total basal area of the plot was  $18.09\text{ m}^2\text{ ha}^{-1}$  with a mean of  $0.72\text{ m}^2\text{ quadrat}^{-1}$ . The highest basal area of the plot was contributed by Combretaceae ( $12.93\text{ m}^2\text{ ha}^{-1}$ ) at family level and *Terminalia tomentosa* ( $5.58\text{ m}^2\text{ ha}^{-1}$ ) at species level. The lowest diameter class (1-10cm) had the highest density ( $1054\text{ individuals ha}^{-1}$ ), but basal area was highest in the 80-90 cm diameter class ( $5.03\text{ m}^2\text{ ha}^{-1}$ ). Frequent visit of people from near villages for daily requirement of fuel, fodder and other non wood forest products leads to destruction of forest causing damage to both plant and animal diversity.

Kumar *et al.* (2010) studied species diversity and soil nutrient status in tropical dry deciduous forests of western India and found that the tree density varied from 458 - 728 stems ha<sup>-1</sup> with average basal area ranging from 5.96 - 19.31 m<sup>2</sup> ha<sup>-1</sup>. Shannon-Weiner index ranged from 0.67 - 0.79, concentration of dominance varied from 0.08-0.16, the species richness index ranged between 21.41 - 23.71, equitability index ranged between 0.02- 0.05 and beta diversity ranged between 2.05 - 4.87. Each of the individual soil variables showed a high positive correlation with tree species richness while tree density showed a clearly negative correlation with variables like phosphorous and nitrogen and positive correlation with carbon.

Pande (2005) studied the ecological status of vegetation in Satpura plateau, M.P. Total density for tree layer ranged between 46.93-387.5 tree ha<sup>-1</sup>, 114 to 714.95 for shrubs and 15905 to 102078 plant ha<sup>-1</sup> for herbs layer. Whereas the range for dominance was 9570 to 217333 cm<sup>2</sup> ha<sup>-1</sup> for trees, 2912 to 32462 cm<sup>2</sup> ha<sup>-1</sup> for shrubs and 1304 to 218468 cm<sup>2</sup> ha<sup>-1</sup> for herbs.

Pande (1999) studied the vegetation of Sal forest of Doon valley and relate the magnitude of disturbance with quantification of vegetation, their resource apportionment and the regeneration of Sal. The whole area was divided into five sites as per their disturbance magnitude. Total basal area (cm<sup>2</sup>/100 m<sup>2</sup>) ranged between 2324-3775 for trees, 74-354 for shrubs and 1.28-30 for herbs. The range of diversity index (Shannon Wiener index) was 0.89-2.31 for trees, 0.87-1.99 for shrubs and 0.64-2.34 for herbs. Diversity index was invariably higher for herbs followed by shrubs and trees. The tree diversity was higher for least disturbed sites (2.31). Whereas, shrubs and herbs density

followed reverse trend. Maximum turnover of tree species was recorded between site I and III (5) and lowest at site II & V (0.25).

Pande *et al.* (2002) studied the vegetation composition, species diversity, distribution pattern and other parameters of vegetation along population structure and regeneration of some tree species in Western Himalayan forests of Chakrata forest division (Uttaranchal). The density for tree species (plant 100 m<sup>-2</sup>) was 4.51-6.64, for shrubs was 23.56-41.62 and for herbaceous species was 7280-11920, while the range for total basal cover was 0.332-0.938 m<sup>2</sup> 100 m<sup>-2</sup> for trees; 9.50-18.81 cm<sup>2</sup> 100 m<sup>-2</sup> for shrubs and 235-323 cm<sup>2</sup> 100 m<sup>-2</sup> for herbaceous species. The maximum diversity of trees was 12 (species richness) and minimum up to 1 for trees, 9-14 for shrubs, 20-23 for herbs. Concentration of dominance (Cd) shows reverse trend to diversity and it was 0.1201 for trees, 0.13-0.15 for shrubs and 0.1 to 0.13 for herbs. Diversity index varies from 0 to 2.25 for trees, 1.53 to 2.31 for shrubs and 2.41 to 2.69 for herbs. Beta diversity between 2 sites of forests shows 4 and 11 for trees, 1.25 and 3.67 for shrubs, 3.8 and 1.2 for herbs.

Patra *et al.* (2007) compared the vegetation of open and closed canopy sal and miscellaneous forest of Satpura plateau and observed that tree density was higher in closed forest than both sal and miscellaneous forest while diversity was higher in open forest. The space created by disturbances in open forest was invaded by other species, which may be the possible cause of higher tree density in open forest. Disturbance magnitude indicates that openness of the stand does not disturb the regeneration and stand development in terms of total tree composition in miscellaneous forest whereas it disturbs the composition of *Shorea robusta* in case of open sal stand of ecotone.

Pitchaitamu *et al.* (2008) have investigated the tree diversity, species richness, basal area, population structure and distribution pattern in moderately disturbed dry deciduous forest of Piranmalai Eastern Ghats in Tamil Nadu and concluded that tree species richness varied along the disturbance of different stands. The undisturbed stand showed the highest species richness and species diversity, disturbed stand show lowest while in the moderately disturbed stand the diversity was higher.

Prasad and Pandey (1992) reported species diversity ranging from 0.32 to 3.76 and concentration of dominance from 0.07 to 0.63 at varying distances from habitation in sal and teak forests in four districts of M.P., India. The forest within 0.5 km radius of habitation recorded lower diversity and dominance compared to forest within 5 km radius of habitation leading to conclusion that there is a decline in biodiversity due to anthropogenic disturbances.

Raghubanshi and Tripathi (2009) have studied the effect of disturbances on floral diversity in dry tropical forests of Vidhyan highland and concluded that species rich communities of dry tropical forests are not only being reduced in area but they are also becoming species poor and less diverse due to rapid deforestation and the community organization is also changing in response to increased anthropogenic disturbance for which previous measures are needed to preserve and conserve whatever intact forest is left so that the alarming trend of disappearance of species rich communities is halted.

Ramanujam and Kadamban (2001) studied the natural vegetation of southeastern coast of Peninsular India and found that it has now been reduced to patches, some of which are preserved as sacred groves. The population structure of woody plants >20 cm GBH (girth at breast height) in two such groves, Oorani and Olagapuram, indicates that

the Oorani grove is a relic of tropical dry evergreen forest, whereas Olagapuram is reduced to thorny woodland.

Rasingam and Parathasarathy (2009) compared the population structure and tree species diversity across major forest formation and disturbance categories at relatively undisturbed and disturbed evergreen (UE,DE), Semi-evergreen (US,DS), deciduous (UD,DD), and littoral (UL,DL) forests in little Andaman Island and found that species richness was lowest (18 species ha<sup>-1</sup>) in DL and highest (84 species ha<sup>-1</sup>) in the UE. Tree density (79 to 935 trees ha<sup>-1</sup>) and basal area (41 to 59.10 m<sup>2</sup> ha<sup>-1</sup>) were greater in all the undisturbed forests as compared to disturbed forests. In all the eight sites, tree species richness and density decreased with increasing girth class and the stand structure of the forests displayed a reverse J-shaped curve, with the exception of the DL.

Rastogi and Rastogi (2007) studied the phyto-sociology of the restored sal plantations and natural sal forest in Tripura and observed that density (stems per ha) of herbs, shrubs and trees varied between 168000-497800, 18800-42112, 1100-2975, respectively. Total basal cover (m<sup>2</sup> ha<sup>-1</sup>) of herbs, shrubs and trees ranged respectively between 0.524 and 941, 0.138 and 0.952, 2.333 and 86.295. Diversity index varied between 0.918 and 0.967 for herbs, 0.743 and 0.876 for shrubs and 0.859 for trees.

Sagar and Singh (2003) analyzed the forest inventory data collected between year 1998 and 2000 of fifteen permanent plots having the size of 1 ha along a disturbance gradient in dry tropical forest regions of India. The study indicate that the dry tropical forest is characterized by a patchy distribution of species and individuals with mixed species composition and different combinations of the dominant and co-dominant species representing the sites. The total number of stems, indices of species richness, evenness

and  $\alpha$ -diversity decreased with disturbance. A strong influence of number of species per individual on  $\beta$ -diversity suggests for resisting change in the floristic composition due to disturbance, a site must have low species individual ratio.

Sagar *et al.* (2008) investigated the differential effect of woody plant canopies on species composition and ground vegetation diversity and concluded that pattern of ground vegetation were controlled by the presence of woody plant canopies while change in the habitat variables such as nature of substrate can affect species diversity. Natural or anthropogenic disturbances can reduce population densities of plant species even further and isolate populations of commonly found species by habitat destruction (De, 2007).

Sahu *et al.* (2010) studied the arboreal taxa diversity of tropical forests of Gandhamardan Hill Range of Eastern Ghats, India having two preservation plots of 100 ha each identified in Nrusinghanath (SITE-I) and Harishankar (SITE-II) range and inventoried a total of 10775 trees belonging to 91 tree species within a 17.6 ha sampled area (441 plots). The Shannon-Weiner index ( $H'$ ) was 3.92 (SITE-I) and 3.31 (SITE-II) with Simpson's value 1.0. This value indicates that the tropical moist deciduous forests are also species diverse systems. Mean stand density was 671  $\text{ha}^{-1}$  in SITE-I and 565  $\text{ha}^{-1}$  in SITE-II and stem density and species richness have consistently decreased with increasing girth class of tree species from 50 cm girth. The present study on phyto-diversity of tree species and participatory approaches on sustainable use of natural resources will provide the baseline information for effective and sustainable biodiversity conservation of tropical moist deciduous forest.

Sahu *et al.* (2008) have studied the influence of altitude and anthropogenic disturbance on forest composition, diversity and structure in a biosphere reserve in

central India and reported that with increasing elevation, basal area increased but number of species, alpha diversity and its components declined monotonically. The number of species and species diversity were positively associated with tree lopping and also with total disturbance while altitude was negatively related with the per cent of trees that were lopped and with total disturbance. Number of species was controlled by stem density only in plots not dominated by *shorea robusta*.

Sen *et al.* (2008) analyzed the composition, dominance and diversity of trees species of the forests of Dadra and Nagar Haveli and stated that the ecological effects of deforestation like increased run-offs and accelerated erosion have affected the edaphic and moisture conditions of the forest, which also reflected the changes in the composition of forest crop. Thus the forest is gradually shifting from a moist deciduous type to a dry deciduous one resembling the dry mixed deciduous forest type (5A/C3).

Shi and Singh (2002) assessed the status of worlds remaining closed forest population distribution and protected areas in global biodiversity hot spots. According to them the worlds remaining closed forests were about 2.87 billion hectares, which occupies about 21.9 per cent of the land area of the world. The high human population pressure in the hot spots exists in 10.7 per cent of closed forests. The four hot spots with the most elevated risk as assessed by human population pressure were in the Western Ghats, Srilanka, Polynesia and Micronesia & Philippines and Caribbean hot spots.

Singh *et al.* (2009) studied the impact of land use pattern on tropical deciduous forest and converted forest of Barnawapara wildlife sanctuary in Chhattisgarh and concluded that both biotic and abiotic factors significantly influence all the characteristics of the ecosystem.

Singh *et al.* (2005) have compared the diversity and dominance of pure sal and degraded moist deciduous forest of Achanakmar wild life sanctuary. The pure sal forest was characterized by high trees density (1233 stems ha<sup>-1</sup>) and understorey vegetation densities (1575 stems ha<sup>-1</sup>) as well as basal cover (tree, 36.36 m<sup>2</sup> ha<sup>-1</sup>; understorey vegetation, 1.85 m<sup>2</sup> ha<sup>-1</sup>). The degraded moist deciduous forest sites represent the degraded stage with low density of tree (633 stems ha<sup>-1</sup>) and basal cover (32.82 m<sup>2</sup> ha<sup>-1</sup>) and under storey plants (density, 918 stems ha<sup>-1</sup>; basal cover, 0.37 m<sup>2</sup> ha<sup>-1</sup>). The total numbers of species was high (30 species) in pure sal forest as compared to degraded moist deciduous forest (19 species). The diversity of plants in pure sal forest was 2.82 (Shannon index), 4.76 (richness index) and 0.99 (equitability index). The diversity of plants was low in degraded forest, the values being 1.99 (Shannon index), 3.48 (richness index) and 0.78 (equitability).

Thakur and Khare (2008) analyzed species composition and diversity in 10 representative forest sites occurring in Sagar district (Madhya Pradesh) were the species richness ranged from 18 to 50, respectively. The beta diversity and Shannon-Weiner diversity index ranged from 0.69 to 1.83 and 2.22 to 3.66, respectively.

Tripathi *et al.* (2004) studied the distribution and community characteristics in subtropical pine forests of Meghalaya and recorded 174 species belonging to 139 genera and 77 families were recorded in different altitudes. The species richness (7.69), diversity (4.13) and evenness (0.26) of the three life forms (tree, shrub and herb) were maximum on the high elevation stand and minimum on the low-elevation stand. Species diversity in the stand was positively correlated ( $r = 0.92$ ,  $P = 0.001$ ) with annual rainfall and negatively ( $r = -0.93$ ,  $P = 0.001$ ) related to the temperature. The dominance of pine

was positively correlated ( $r = 0.89$ ,  $P = 0.001$ ) with temperature but negatively correlated ( $r = -0.89$ ,  $P = 0.01$ ) with mean annual rainfall. The tree density varied between 810 and 1050 stem  $\text{ha}^{-1}$  and basal covers from 28.9 to 37.4  $\text{m}^2 \text{ha}^{-1}$ .

Upadhyay (2008) has assessed the diversity and regeneration of woody species in sacred forest of northeast India along the human disturbance and found that the species richness in disturbed stands was significantly lower (24-26) than the undisturbed stands (32-60) and basal area was higher in undisturbed stands (27-62  $\text{m}^2 \text{ha}^{-1}$ ) than disturbed stands (3.14-58.25  $\text{m}^2 \text{ha}^{-1}$ ). The density of seedling and saplings were significantly higher in the undisturbed stands than the disturbed stands.

Upadhyay *et al.* (2008) studied the community structure, diversity and regeneration status in moist deciduous forest of Indo Gangetic plain and concluded that diversity index and species richness were highest for inner undisturbed site and also found a non linear reduction in girth distribution pattern with increasing diameter classes. Population density decreased from 486  $\text{ha}^{-1}$  in undisturbed site to 82  $\text{ha}^{-1}$  in disturbed while the population structure of common trees showed poor regeneration.

Verghese and Menon (1998) conducted studies in south moist mixed deciduous forests of Agasthyamalai region of Kerala, India through quadrat sampling method. The stand density, species density and basal area of these forests were 535 trees  $\text{ha}^{-1}$ , 12 species per 0.1 ha and 26.57  $\text{ha}^{-1}$ , respectively. Shannon index of these forests was 1.89, while evenness index was 0.73. *Terminalia paniculata*, *Pterocarpus marsupium* and *Careya arborea* were found as dominant plant association.

Yadav and Singh (2010) studied the four site of one ha area for community structure and floristic diversity of tree layer having dense, medium, regenerated and

degraded forest plot in the Achankmar-Amarkantak Biosphere reserve. A total of 33 species were recorded. Density and basal area of trees ranged from 240 (degraded forest) to 1270 (regeneration forest) stems  $\text{ha}^{-1}$  and 23.65 (regeneration forest) to 37.57 (dense forest plot)  $\text{m}^2 \text{ha}^{-1}$ , respectively. Diversities in these forests plots were 1.46 to 2.24 (Shannon index), 0.61 to 0.83 (equitability), 2.95 to 6.06 (species richness), 0.41 to 0.53 (concentration of dominance) and 4.05 to 12.8 (Beta diversity). The beta diversity was highest at distributed forest plot.

Shannon Wiener diversity indices are generally higher for tropical forests, that ranges between 0.81 and 4.1 for the Indian sub continent (Singh *et al.*, 1984; Parthasarathy *et al.*, 1992; Visalakshi, 1995; Pande, 1999, 2001). Vishalakshi (1995) reported Shannon Wiener diversity between 0.83 and 2.43 for Marakkanam reserve forest in south India. The values of concentration of dominance (Cd) for tropical forest lie within the range of 0.21 to 0.92.

In several temperate forests the value of total basal cover and density were 0.15-0.6  $\text{m}^2/100 \text{m}^2$  and 3.2-20.8 tree/100  $\text{m}^2$ , respectively (Saxena and Singh, 1982; Singh *et al.*, 1997). The same ranges from 0.11-0.68  $\text{m}^2/100 \text{m}^2$  and from 5.5-18 trees/100  $\text{m}^2$  for tropical forests (Visalakshi, 1995; Parthasarathy *et al.*, 1992). The diversity values reported in temperate forest were between 1.16 and 3.4 by many workers.

### **2.3 Biomass Pattern**

Biomass constitutes a primary data needed for understanding a number of ecological processes like energy flow, water and nutrient cycling in forest ecosystems (Chaturvedi and Singh, 1987; Tiwari, 1994). On the other hand, the estimation of woody biomass is also necessary for determining the storage and flux of biological materials in

an ecosystem (Anderson, 1970). The quantity of tree biomass per unit land area forms the primary data needed to understand the flow of materials and water through forest ecosystems (Swank and Schreuder, 1974).

The biomass estimations in forests are conventionally made by the use of species specific allometric equations and component wise viz., stem, branch, foliage and root biomass are estimated in both tree and shrub layer (Misra, 1968; Odum, 1983; Rai, 1984). In this approach, the availability of species-specific local regression equations is essential for precisely estimating the forest biomass.

Adhikari *et al.* (1995) enumerated that total biomass was 505 t ha<sup>-1</sup> in horse chestnut, 566 t ha<sup>-1</sup> in silver fir and 593 t ha<sup>-1</sup> in Kharsu oak forests of which maximum contribution was by tree layer followed by shrub, herb, sapling and seedling layers. The forest floor biomass was 2.1, 4.7 and 4.2 t ha<sup>-1</sup> in horse chestnut, silver fir and kharsu oak forests, respectively. The total litter fall was 7.3, 6.7 and 9.4 t ha<sup>-1</sup>, of which leaf litter contributed 48, 39 and 64 % of horse chestnut, silver fir and kharsu oak forest, respectively. Turnover rate of tree litter was 0.80, 18.9 and 24.9 t ha<sup>-1</sup> yr<sup>-1</sup> of which tree layer contributed maximum proportion followed by herb, shrub, sapling and seedling layers.

Baisya *et al.* (2009) studied above ground biomass distribution and carbon storage in different DBH and compared between natural semi evergreen forest and sal plantation in the humid tropics of NE India. They found that the above ground biomass in natural forest was higher in the trees having DBH > 60 cm as compared to plantation forests.

Brown *et al.* (1997) examined quantities and distribution of above ground biomass density (AGBD, Mg ha<sup>-1</sup>) of US eastern hardwood forests and assessed their

biological potential for continued biomass accumulation in the future and found that the presence of a large proportion of the AGBD of moist tropical forests in large diameter trees (> 70 cm diameter) which indicate the mature and undisturbed conditions. Biologically these forests have potential to accumulate significant quantities of additional biomass, if left unharvested.

Cairns *et al.* (2003) estimated aboveground tree biomass of a dry semi-evergreen forest of Mexico's Yucatan Peninsula and stated that a total of 72 species were found in a 0.5 ha stand with a basal area of 31.3 m<sup>2</sup> ha<sup>-1</sup> constituting about 225 Mg ha<sup>-1</sup> of total aboveground tree biomass which was dominated (85%) by the biomass of the large trees.

Cairns *et al.* (2000) studied Tropical Mexico's recent land use and change: a region's contribution to the global carbon cycle and stated that the above ground biomass of two tropical moist forest ecosystems (i.e., Guerrero and Chiapas) was 41.10 Mg ha<sup>-1</sup> and 133.10 Mg ha<sup>-1</sup>, respectively.

Castellanos *et al.* (1991) studied the root biomass of dry deciduous tropical forest in Mexico and found that the above and below ground biomass of trees, shrubs and lianas was 73.6 t ha<sup>-1</sup> and 31 t ha<sup>-1</sup>, respectively. A root: shoot biomass ratio of 0.42 was calculated. Gerwing (2002) tried to understand the implications of forest degradation by comparing the impacts of varying intensities of logging on forest structure and composition in the eastern Brazilian Amazon Forests and found that 20 to 40 per cent reduction in the above ground live biomass was due to logging.

Cummings *et al.* (2002) found that TAGB of tropical moist forest in northern Rondonia, Brazil varied from 288 to 534 Mg ha<sup>-1</sup>. Similarly, Heider (2001) reported that

TAGB of 18 Mexican tropical wet forests ranged from 309 to 550 Mg ha<sup>-1</sup> of which biomass of individual large trees (130 cm dbh) ranged from 11 to 43 Mg.

Hall and Uhling (1991) estimated the biomass density of forest in South and South East Asia using the volume estimates and biomass comparison factors derived from Brown *et al.* (1989). Their biomass estimates for India ranged from 116 Mg ha<sup>-1</sup> for undisturbed forest for 60-80 years and 35, 66 and 84 Mg ha<sup>-1</sup> for logged, unproductive and managed forests, respectively. However, these estimates were only made from 9 per cent of forest area and no information was given in relation to forest types and species composition.

HariPriya (2000) estimated the above ground biomass density and carbon storage in biomass of major forest strata (21) of India from data collected from 1,70,000 sampling units distributed all over the country in 1993. Biomass densities ranged from 14 to 210 Mg ha<sup>-1</sup> with a mean of 67.4 Mg ha<sup>-1</sup>, which equals around 34 Mg ha<sup>-1</sup>.

Karia and Kiran (2004) analyzed the physicochemical properties of soil under different forest classes i.e. closed teak forest, closed mixed forest, open mixed forests, degraded forest, scrub and scrub with coppice forests of Sajwa, Kalarani and borial surrounds of Chhotaudepur forest division. Soils had a higher nutrient status in their topsoil. Some exceptions have been observed where the concentration of micronutrients like Mn, Fe and Cu and macronutrients like N, P and K increased in sub-surface soils. Fe and N in closed mixed forest and degraded forest, Cu and Fe in degraded and scrub forest and P and K in open mixed forest increases in sub-surface soils. The concentration of macro and micronutrients were also in good amount. Thus it shows that the soils of the forests at present are in good shape.

Kumar (2008) investigated the litter production in two age groups of *Acacia auriculiformis*. Periodic collection and quantification of different litter components of 3 years old and 6 years old monoculture plantations of *Acacia auriculiformis* for two consecutive years has been done. The litter was separated into phyllode twig + wood and fruit + inflorescence. The litter production was 5.27 to 6.80 t ha<sup>-1</sup> yr<sup>-1</sup> in three year old plantation and 9.56 to 11.78 t ha<sup>-1</sup> yr<sup>-1</sup> in six years old plantation.

Leith and Whittaker (1975) pointed out that if forest biomass is measured and analyzed in its proper context as part of production, an overall picture of ecosystem functioning can be gained. The biomass and productivity of tree species varies from place to place due to variation in climate, soil, temperature and rainfall.

Mishra *et al.* (1998) studied the biomass status of two sites- a biotically disturbed site (BD) and an undisturbed site (UD) of mixed dry deciduous forest of Shiwalik hill in Haryana. The total basal area was 7.9 m<sup>2</sup> ha<sup>-1</sup> in BD and 9.7 m<sup>2</sup> ha<sup>-1</sup> in UD. Three important tree species *Anogeissus latifolia*, *Acacia catechu*, and *Terminalia tomentosa* accounted for 88% of total tree density in BD and 66% in UD. Total above ground tree biomass was 22.05 t ha<sup>-1</sup> in BD and 31.19 t ha<sup>-1</sup> in UD, indicating a significant difference.

Murali *et al.* (2005) derived biomass estimation equation for tropical deciduous and evergreen forests and developed linear and non-linear regression equations for estimation of biomass of tropical forests along with estimates of goodness of fit and percentage of errors. Basal area and height of trees were found to give high goodness of fit and low percentage of errors for deciduous forests. They found that generally the coefficient of determination ( $r^2$ ) was low for evergreen forests. The coefficient of determination was high and estimate of error was low for deciduous forests. They

concluded that the biomass estimation equations for deciduous forests were precise and therefore useful for field applications.

Murphy and Lugo (1986) observed that the total litterfall in dry and wet tropical forests was between 3-10 t ha<sup>-1</sup>yr<sup>-1</sup> and 5.0-14.0 t ha<sup>-1</sup>yr<sup>-1</sup>, respectively. Rai and Proctor (1986) estimated that the litter production of rain forest in Karnataka, India was between 3.4 and 4.2 t ha<sup>-1</sup>yr<sup>-1</sup>.

Nascimento and Laurance (2002) studied total above ground biomass in central Amazonian rain forests and quantified total above ground dry biomass (TAGB) within 201 ha plots in undisturbed site. TAGB values were very high averaging 397.7 ± 30.0 t ha<sup>-1</sup>. The most important component of above ground biomass were large trees (< or ≥ 10 cm dbh) which comprised 81.9% of TAGB followed by downed wood debris (7.0%), small trees, saplings and seedlings (< 10 cm dbh; 5.3%), lianas (2.1%), litter (1.9%), snags (1.5%) and stemless palms (0.3%). Among large trees above ground biomass was greatest in intermediate sized (20-50 cm DBH) stems (46.7% of TAGB), with very large (< or ≥ 60 cm DBH) trees also containing substantial biomass (13.4% of TAGB). They also found that there were no significant correlations between large tree biomass and that of any other live or dead biomass components.

Oliveria *et al.* (2003) tested the hypothesis, that there are significant impacts in above ground alive standing biomass among areas under fragmentation and evaluated the standards of biomass distribution among four areas around the highways BR364 and BR 364 (Acre, Brazil) through allometric equations and found that the dynamics of biomass in primary forests are related to the process of forest fragmentation. They found the smallest values for the variable basal area (20.3 m<sup>2</sup> ha<sup>-1</sup>) and biomass (384 tons ha<sup>-1</sup>) in

the smallest forest fragments. The effect of selective logging was evident and showed a drastic reduction in biomass for the logged species.

Pande *et al.* (1986) studied the biomass production and distribution of nutrients in moist deciduous forests in Goa and found that the dominant species was *Terminalia tomentosa* in the upper storey and *Careya arborea* and *Lannea grandis* in the under storey and reported that as much as 92% of the total biomass was contributed by *Terminalia tomentosa* with only 8% by the other two species.

Raizada *et al.* (2007) estimated the biomass production and prediction models for *Acacia nilotica* in salt affected vertisols in Karnataka and they observed that although the plantation is even-aged, there were wide variations in diameter (3.1 to 16 cm) in the entire block and 9.3 to 15.4 cm in the sampled trees. Tree height also varies from 3.5 to 5.1 m, which in turn has influenced above ground biomass. Utilizable biomass (bole + bark + leaf) for firewood ranged from 18.3 to 72.64 kg/tree and total above ground biomass ranged from 26.50 to 100.74 kg/ tree.

Read & Lawrence (2008) stated that the above ground biomass of Calakmul tropical forest ecosystem was 136.42 Mg ha<sup>-1</sup> in their study recovery of biomass following shifting cultivation in dry tropical forests of the Yucatan, Mexico.

Roy and Ravan (1996) estimated the biomass in tropical dry deciduous forest of Madhav National Park of Madhya Pradesh using two approaches viz., Homegensces vegetation stratification (HVS) and spectral response model. The biomass estimated for the entire national park through stratified and spectral response modeling approached were compared and it showed only a small difference of 4.69 per cent between two

approaches. Total biomass of the different community type of dry tropical forests ranged from 7.42 to 52.41 t ha<sup>-1</sup>.

Shrestha *et al.* (2000) analyzed the vegetation of natural and degraded forests in Chitrepani in Siwalik region of Central Nepal and stated that the natural and regenerating forest sites had much higher tree density than the degraded forest site as it had lost more than 70% species, 90.9% plant density, 80.0% basal area and 80.1% tree biomass. The above ground live biomass of trees was highest in natural site (807 t ha<sup>-1</sup>) while degraded site, had the lowest value (160 t ha<sup>-1</sup>).

Singh and Singh (1991) studied the species composition, plant biomass and diversity index in mixed dry deciduous forests of Vindhyan region and found that the mean standing biomass of vegetation was 66.98 t ha<sup>-1</sup> with 46.70 t ha<sup>-1</sup> in tree layer & 2.83 t ha<sup>-1</sup> in the fine roots. A total of 83 per cent vegetation carbon was stored in above ground plant parts, while the above ground NPP was responsible for 72 per cent of the total carbon input into the system.

Singh *et al.* (2009) investigated the impact of land use change on species structure, biomass and carbon storage in tropical dry deciduous forest and converted forest and found that the total biomass in natural forest was 192.933 Mg ha<sup>-1</sup> and 95.64 Mg ha<sup>-1</sup> in 32 years old converted forest. The total above ground biomass in different forest plots ranged from 71.94 to 162.91 Mg ha<sup>-1</sup> with highest in natural forest and lowest in 23 years old converted forest. The below ground biomass varied from 13.97 to 30.02 Mg ha<sup>-1</sup> following the similar trend as above ground biomass.

Swamy *et al.* (2010) have studied the biomass, litterfall and net primary productivity (NPP) of tropical evergreen forests of western Ghats, India and concluded

that total stand biomass averaged from 440 to 571 mg ha<sup>-1</sup>, of which trees contributed 90.2-92.2% and remaining 8.8-9.8% contributed by shrubs and herbs. The standing litter ranged from 3.5 to 4.2 mg ha<sup>-1</sup> and litter production from 4.0 to 5.7 mg ha<sup>-1</sup> yr<sup>-1</sup>. The average NPP was 23.7 mg ha<sup>-1</sup> yr<sup>-1</sup>, of which 64.7% was contributed by trees, 13.6% by shrubs, 2.7% herbs and 19.1% by litter, Turnover rate and turnover time ranged from 0.93 to 0.95 yr<sup>-1</sup> and 1.05 to 1.08 yrs, respectively.

Thakur and Khare (2010) investigated the changing status of forest vegetation of Patharia hills at Sagar in India and mentioned that the topography, soil properties and extent of human disturbances are attributed as the major factor influencing the vegetation structure and biomass.

Upadhyay *et al.* (2009) analyzed that effect of disturbance on standing biomass in a sal mixed forest of Eastern U.P. Three sites selected on the basis of disturbance gradient showed sequential differences in standing biomass. The total biomass of the three forest sites differs significantly from severely disturbed site I to relatively undisturbed site III of which 83% was allocated to above ground parts and 17% to below ground. The understory contributed about 32% (172 t ha<sup>-1</sup>) and overstorey layer constituted about 68% (372 t ha<sup>-1</sup>) in the total biomass.

Vitousek and Sanford (1986) have reported that total litterfall in tropical moist forest ranged from 3.6 to 12.4 t ha<sup>-1</sup>yr<sup>-1</sup>.

Wilsey and Potvin (2000) reported that total and belowground biomass increased with increasing levels of species evenness. Studies on biodiversity in relation to ecosystem functioning have revealed that species diversity enhances the productivity and stability of ecosystems (Naeem *et al.*, 1994; Tilman *et al.*, 1996).

## *MATERIALS AND METHODS*

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## CHAPTER-III

### MATERIALS AND METHODS

“A Study on the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest” was carried out at Katghora Forest Division under Bilaspur Circle of Korba district (Chhattisgarh) during the year 2010-2011. The details of the study site, climate, soils, flora, fauna and other features of study area with the methodologies used were described below:

#### 3.1 Study site

The study was conducted in compartment No.929 and Narangi vankhand of Katghora Forest Division under Bilaspur Circle situated in Korba district. The geographical location and physiographic features of study area are given below.

##### 3.1.1 Geographical location and physiography

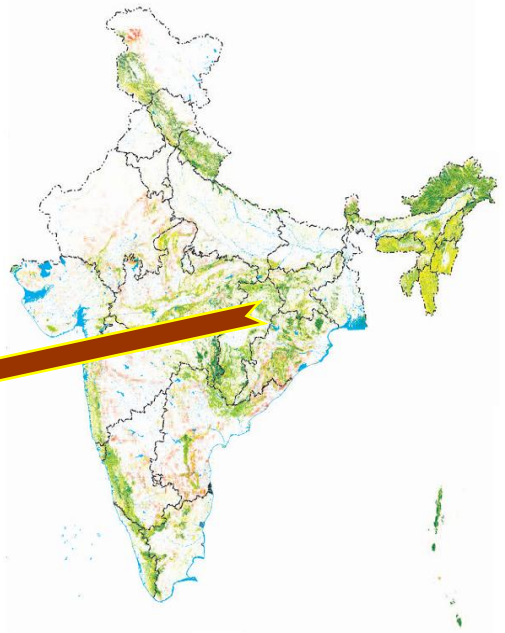
The study area was located between 22° 26' 49" to 22° 28' 74" North latitudes and 82° 19' 30" to 82° 22' 97" East longitudes. It was situated about 200 km away from Raipur. The study area comprises about 4187.371 sq. km of which 2834.968 sq. km was protected forests area and 1352.403 sq. km was unclassified forests. The location of study area was depicted in Fig. 3.1.

Physiographically the area comes under Satpura and Maikal Mountain ranges and generally the topography was undulated. The area lies at an altitude of 900-940 feet above from mean sea level. The basic Physiographic regions were as follows:

- |    |                         |         |
|----|-------------------------|---------|
| 1. | Mountains               | 27.50 % |
| 2. | Plateau and pat regions | 29.29 % |

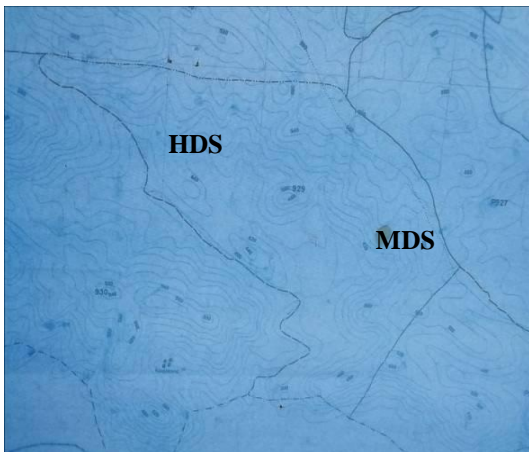


**CHHATTISGARH**

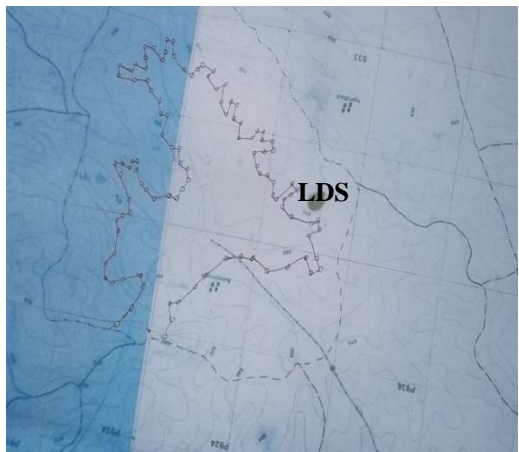


**INDIA**

**KATGHORA**



**Compartment No. 929**



**Narangi vankhand**

**FIG. 3.1: LOCATION MAP OF STUDY AREA**

3. Plains River basins 43.21 %

### **3.1.2 Climate**

The climate of study area was sub humid to humid from west to east and also being monsoonal, with three distinct seasons prevailing viz., winter (Nov-Feb), summer (Mar-June) and rainy (July–Oct). The study area comes under tropical upland region. The rainy season commences from about the middle of June. The winter season, which commences from the beginning of November, lasts till the end of February. The summer commences from the beginning of March. It is quite prolonged and lasts till monsoon sets in.

### **3.1.3 Rainfall**

The average annual rainfall in the study area ranges from 1000 mm – 1250 mm. It gradually decreases from South East direction to North West direction. About 80 per cent of the rainfall in the study area is received from south west monsoon during June to August. The highest amount of rainfall occurs in July.

### **3.1.4 Temperature**

The mean annual maximum temperatures during summer is 38.80°C and mean annual minimum temperature is 28°C while the minimum temperature during winter is 24.50°C.

### **3.1.5 Humidity**

Relative humidity of study area increases with the onset of south-west monsoon and it generally becomes more than 84% in July. In the post monsoon and winter season the relative humidity lies between 56-74% in the morning (6:00 to 12:00 hrs.) and 36-65% in the afternoon (12:00 to 16:00 hrs.). Relative humidity is lowest during summer

and drops below 30 per cent in the afternoon in April and May. The humidity of the area varies from 37-87% in the morning (6:00 to 12:00 hrs.) and 22-81% in the afternoon (12:00 to 16:00 hrs.).

### **3.1.6 Soils**

Three types of soils are found in study area i.e. red soil, laterite soil & mountain soil. The soil has a good content of organic matter, which affects various properties of soil. pH of soil varies from 6-8. Water holding capacity is good, cation exchange capacity is high, soil profile is well developed, soil is loamy to sandy loam in texture, natural clods are developed which have granular or crumbly structure. The soil is rich in nutrients especially under plantation areas, diversity of soil micro fauna and micro flora is abundant. The compactness and consistency of soil varies from place to place, soil aeration and soil water are affected by the texture and organic matter content. Simply soil is terrible faced which accommodate a good diversity of vegetation.

### **3.1.7 Forest types and flora**

Different types of forest vegetation occur in the study area. According to Champion and Seth (1968), the forest of the study area are classified into the following forest types and subtypes

(1). Northern Tropical Dry Deciduous Forests - 5/B

1.1 Northern Tropical Dry Deciduous Peninsular Sal Forests - 5B/C1C

1.2 Northern Tropical Dry Mixed Deciduous Forests - 5B/C2

1.2.1 Salai Forests - 5B/C2/E2

1.2.2 Khair-Sisoo Forests - 5B/C2/S2

## (2). Northern Tropical Moist Deciduous Forests - 3C

### 2.1 Northern Tropical Moist Peninsular Sal Forests - 3C/C2C

#### 2.1.1 High Level Sal Forests - 3C/C2C (i)

#### 2.1.2 Dry Bamboo Brakes - 3C/C2/S2

### 2.2 Northern Tropical Moist Mixed Deciduous Forests - 3C/C3a

## **3.2 Experimental details:-**

### **3.2.1 Sampling /Ground Inventory**

A Study on Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass pattern of Three Sites of Tropical Deciduous forest was conducted at Katghora Forest Division. Three sites were selected to quantitatively compare the diversity, forest vegetation structure and biomass between areas facing high pressure of biomass extraction and those that are better protected and currently facing little anthropogenic pressure i.e. least, moderately and highly disturbed site.

### **3.2.2 Method**

At each site, the vegetation was sampled in ten randomly placed quadrats. The latitude, longitude and altitude were recorded by global positioning system and the proportion of trees showing signs of lopping were recorded. Lopping score for each tree was additionally measured at each quadrat on a scale of 0-4, as follows-0: no lopping; 1: rudimentary signs of lopping; 2: up to half of the main branches lopped; 3: more than half of main branches lopped and 4: tree reduced to a stump.

Regeneration status, species diversity and structure of tree species were studied during 2010–2011. For the study of regeneration and species diversity 10 m x 10 m quadrats for trees and saplings were laid. Inside 10 m x 10 m quadrats, 2 m x 2 m

quadrats were laid for the enumeration of seedling on the forest floor and counted separately for each species. Species area curve was used to determine minimal sample area which is based on quantitative variation of the vegetation in terms of species number (Muellor-Dombios and Ellenberg, 1974).

In each 10 m × 10 m quadrat, individuals having >30 cm CBH (circumference at breast height, i.e. 1.37 m above the ground) were considered trees and were measured species-wise. Individuals having <10 cm circumference were considered as seedlings and those having the intermediate position with respect to these circumferences were considered as saplings (Singh *et al.*, 2006). The density of seedlings and saplings is considered as an indicator of the regeneration potential. From the field data, phyto-sociological parameters of trees, saplings and seedlings were calculated following Misra (1968).

### **3.2.3 Regeneration**

The status of regeneration of species was determined based on population size of seedlings and saplings (Shankar, 2001). The status of sampled species was assessed based on one time phyto-sociological data in the following categories. (a) good, if seedlings > saplings > adult; (b) fair, if seedlings > saplings ≤ adults; (c) poor, if a species survives in only sapling stage, but not as seedlings (though saplings may be less, more or equal to adults); (d) none, if a species is absent both in sapling and seedling stages, but present in adults; and (e) new, if a species has no adults, but only saplings and/or seedlings.

### **3.2.4 Phytosociological analysis**

The vegetation data in each forest plot was quantitatively analyzed for frequency, density and basal cover following Curtis and McIntosh (1950). Following expressions were used for the calculations of frequency, density and basal covers.

$$\text{Frequency (\%)} = \frac{\text{Number of sampling units in which species occurred}}{\text{Total number of sampling units studied}} \times 100$$

$$\text{Density (tree/ha)} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Number of quadrats in which the species occurred}}$$

Basal area of trees was calculated as cross sectional area of stem at breast height i.e. at 1.37 m from the ground level. The relative frequency, relative density and relative basal area, were calculated following equations.

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of the individual species}}{\text{Total frequency of all the species}} \times 100$$

$$\text{Relative density (RD)} = \frac{\text{Density of the individual species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative basal area (RBA)} = \frac{\text{Basal area of the individual species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Relative abundance (RA)} = \frac{\text{Abundance of the individual species}}{\text{Total abundance of all species}} \times 100$$

The Importance Value Index (IVI) was determined as the sum total of relative frequency, relative density and relative basal area (Phillips, 1959).

$$\text{Importance Value Index (IVI)} = \text{RD} + \text{RF} + \text{RBA}$$

### 3.2.5 Plant diversity analysis

Plant diversity in different forest plot was quantified following Sagar and Sing(1999).

#### a) Shannon Index

Shannon - Weaver information function (Shannon and Weaver, 1963) was used for the species diversity

$$H' = \sum p_i \log_2 p_i$$

where,

$p_i$  was the proportion of total stand basal cover represented by the  $i^{\text{th}}$  species.

The working formula given by Smith (1974) was used here

$$H' = 3.3219 \left[ \log_{10} N - \frac{\sum N_i \log_{10} N_i}{N} \right]$$

where,

$N_i$  was the total basal cover of species  $i$  and  $N$  was the total basal area of all the species. The factor 3.3219 was used to convert the index value to  $\log_2$ .

**b) Concentration of dominance** was measured by Simpson Index (Simpson, 1949).

$$Cd = \sum \left[ \frac{N_i}{N} \right]^2$$

where,

$N_i$  = the total basal cover of species  $i$

$N$  = the total basal area of all the species.

c) **Equitability (e)** was calculated as suggested by Pielou (1966).

$$e = \frac{H'}{\ln S}$$

where,

$H'$  = Shannon index

$S$  = the number of species.

d) **Species richness** was calculated following Margalef (1958).

$$D = \frac{S-1}{\ln N}$$

where,

$S$  = total number of species,

$N$  = basal area of all species

e) **Beta diversity** was calculated following Whittaker (1972).

$$\beta d = \frac{S_c}{\bar{s}}$$

where,

$S_c$  = total number of species in all sites and

$\bar{s}$  = average number of species per site.

These indices were calculated following Sagar and Singh (1999).

### **3.2.6 Biomass estimation**

For the measurement of tree biomass, allometric equation relating tree circumference to biomass developed earlier by Singh and Mishra (1979) for the dry deciduous forest species were used (Appendix I). The tree individuals in each quadrat were categorized into different girth classes. The mean CBH (circumference at breast height) value for each species for a girth class was used in the regression equation to get an estimate of biomass (by component) for that girth class. Then this value was multiplied by the density of trees in that girth class. The girth class values were summed to obtain the biomass estimate for each of the quadrats in each site.

The relationship between girth of a tree and dry weight of a component is given by equation:

$$\mathbf{Log\ Y = a + b\ log\ X}$$

where,

Y = dry weight (kg) of component (bole, branch, leaf and root)

X = girth (cm) at 1.37 m height

a and b = allometric constants.

By using 50 x 50 cm randomly placed quadrats, forest floor litter was collected and then categorized into different component viz., fresh leaf, wood and partially decomposed litter. The collected litter was brought to the laboratory and oven dry weights were determined.

### **3.2.7 Soil analysis**

Composite soil samples (0-10cm & 10-20cm) were collected from each study site. The pH of each soil sample was determined using a digital pH meter. Bulk density and

soil texture was determined following Misra (1968). Concentration of organic carbon and nitrogen were estimated using CHNOS Auto Analyser. Available phosphorus and potassium were determined following Jackson (1958).

### **3.2.7 Statistical analysis**

For collection of data quadrats were selected under stratified random sampling design considering three sites viz., least, moderately and highly disturbed site as strata. In order to understand the effect of different sites on various variables viz., density, basal area and biomass, Bartlett's test was carried out to insure the homogeneity of variances within different sites. After insuring homogeneity of variances one way analysis of variance was carried out to test the equality of means due to different sites for various variables viz., density, basal area and biomass.

Further a correlation and regression study was performed to assess the impact of altitude and lopping intensity on the variables viz., density, basal area and biomass. Form of linear regression ( $y = a+bx$ ) was estimated along with the estimation of underline correlation coefficient ( $r$ ). The relevant parameters like  $r$ ,  $a$  &  $b$  were tested for their significance at 5 or 1 % levels of significance following Snedecor and Cochran (1967).

## *RESULTS AND DISCUSSION*

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## **CHAPTER-IV**

### **RESULTS AND DISCUSSION**

The results on “A Study on the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest” are discussed in this chapter. The findings are presented in three parts to facilitate the interpretation of results in accordance with topics. First part deals with the results on quantification of effect of protection on regeneration status, the second part deals with the results on quantification of effect of protection on species diversity and species structure (phytosociological analysis) and the third part deals with the results on quantification of effect of protection on biomass pattern in various forest sites of tropical deciduous forest of Katghora division. Results on different aspects in each part are described below:-

#### **4.1 Quantification of effect of protection on regeneration status on various forest sites**

The renewal of the tree crop by natural means in the form of crop is the indication of the health of site, recruitment and establishment of regenerating plants of tree species. The density of seedlings (Table 4.1) was found to be 39500 stems ha<sup>-1</sup> on least disturbed site, 26000 stems ha<sup>-1</sup> on moderately disturbed site and 7750 stems ha<sup>-1</sup> on highly disturbed site.

Similarly, density of sapling (Table 4.1) was found to be 490 stems ha<sup>-1</sup> on least disturbed site, 610 stems ha<sup>-1</sup> on moderately disturbed site and 30 stems ha<sup>-1</sup> on highly disturbed site. The basal area of sapling layer was 1.24, 1.63 and 0.06 m<sup>2</sup> ha<sup>-1</sup> on least disturbed, moderately disturbed and highly disturbed site, respectively.



**Plate 4.1: A view of least disturbed site**



**Plate 4.2: A view of regeneration status on least disturbed site**



**Plate 4.3: A view of forest floor (litter) on least disturbed site**



**Plate 4.4: A view of moderately disturbed site**



**Plate 4.5: A view of regeneration status on moderately disturbed site**



**Plate 4.6: A view of forest floor (litter) on moderately disturbed site**



**Plate 4.7: A view of highly disturbed site**



**Plate 4.8: A view of regeneration status on highly disturbed site**



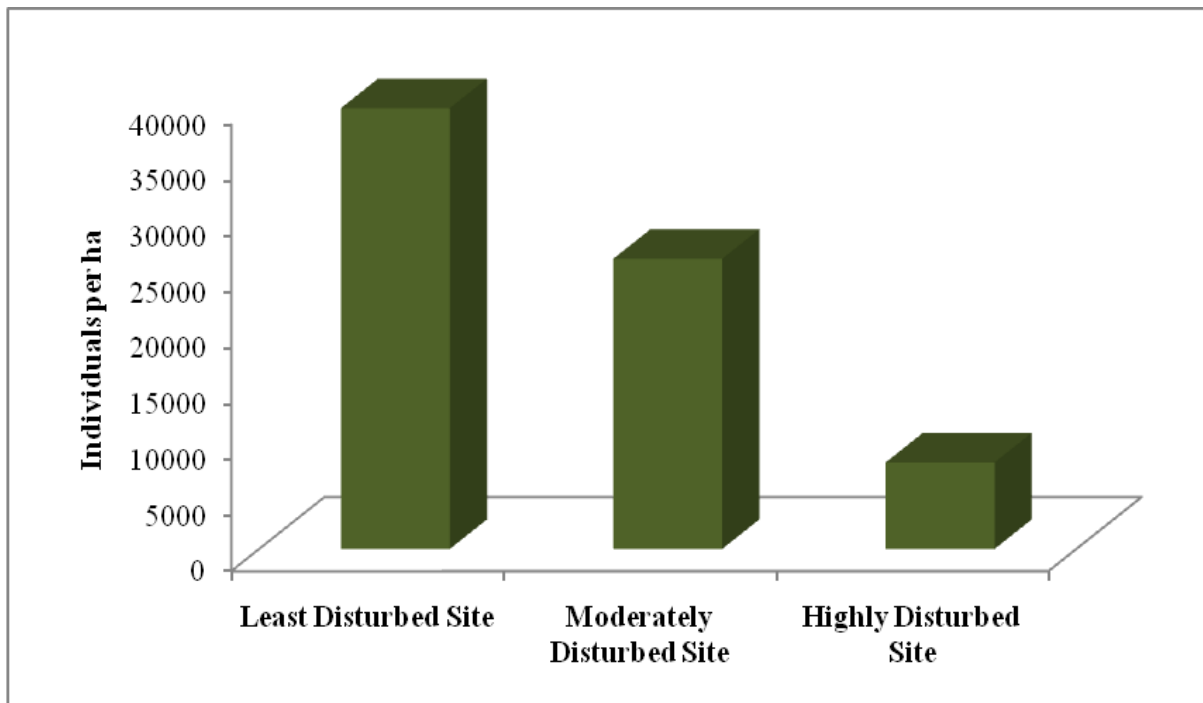
**Plate 4.9: A view of forest floor (litter) on highly disturbed site**

The status of regeneration of species was determined based on population size of seedlings and saplings. Good regeneration, i.e. if particular species is present in seedling > sapling > tree; fair regeneration, i.e. if species is present in seedling > sapling < tree; poor regeneration, i.e. if a species survives only in sapling stage, but not as seedling; if species is present only in adult form it is considered as not regenerating. A species is considered as not abundant if the species has no tree representatives, but only sapling and/or seedlings.

The tree density on least disturbed, moderately disturbed and highly disturbed sites varied greatly and it was highest on least disturbed site (510 stems ha<sup>-1</sup>) followed by moderately disturbed site (310 stems ha<sup>-1</sup>) and lowest on highly disturbed site (100 stems ha<sup>-1</sup>). The sapling density was highest on moderately disturbed site (610 stems ha<sup>-1</sup>) followed by least disturbed site (490 stems ha<sup>-1</sup>) and lowest on highly disturbed site (30 stems ha<sup>-1</sup>) while seedling density was highest on least disturbed site (39500 stems ha<sup>-1</sup>) followed by moderately disturbed site (26000 stems ha<sup>-1</sup>) and lowest on highly disturbed site (7750 stems ha<sup>-1</sup>; Fig. 4.1).

The highest tree density on least disturbed site was recorded for *Shorea robusta* (170 stems ha<sup>-1</sup>) followed by *Madhuca latifolia* (130 stems ha<sup>-1</sup>) and *Syzygium cumini* (60 stems ha<sup>-1</sup>). The highest tree density at moderately disturbed site was recorded for *Holarrhena pubescens* (100 stems ha<sup>-1</sup>) followed by *Lagerstroemia parviflora* (90 stems ha<sup>-1</sup>) whereas on highly disturbed site, the highest tree density was recorded for *Terminalia alata* (40 stems ha<sup>-1</sup>) followed by *Shorea robusta* (20 stems ha<sup>-1</sup>; Table 4.1).

A total of 10 tree species, 9 saplings and 14 species of seedlings were found on least disturbed site. The highest density for seedling was recorded for *Shorea robusta*



**Fig.4.1** Distribution pattern of seedlings on three different sites

(13500 stems ha<sup>-1</sup>) followed by *Diospyros melanoxylon* (7000 stems ha<sup>-1</sup>) and *Madhuca latifolia* (6750 stems ha<sup>-1</sup>). The lowest seedling density (250 stems ha<sup>-1</sup>) was recorded for *Bahuinia variegata*, *Casearea graveolens*, *Casine albeus*, *Semicarpus anacardium* and *Terminalia chebula*. The highest sapling density was recorded for *Madhuca latifolia* (130 stems ha<sup>-1</sup>) followed by *Shorea robusta* (100 stems ha<sup>-1</sup>) and *Diospyros melanoxylon* (90 stems ha<sup>-1</sup>). The lowest sapling density was represented by *Pterocarpus marsupium*, *Semicarpus anacardium*, *Syzygium cumini* and *Terminalia alata* (10 stems ha<sup>-1</sup>; Table 4.1).

A total of 12 species of trees, 8 of seedlings and 9 species of saplings were found on moderately disturbed site. The maximum seedling density (19000 stems ha<sup>-1</sup>) was recorded for *Holarrhena pubescens* which is followed by *Lagerstroemia parviflora* (2750 stems ha<sup>-1</sup>). The lowest seedling density (250 stems ha<sup>-1</sup>) was recorded for *Cassine albeus*. The highest sapling density (250 stems ha<sup>-1</sup>) was recorded for *Holarrhena pubescens* followed by *Lagerstroemia parviflora* (160 stems ha<sup>-1</sup>). The lowest sapling density (10 stems ha<sup>-1</sup>) was represented by *Flacourtia indica*, *Lannea coromandelica* and *Semicarpus anacardium* (Table 4.1).

A total of 6 tree species, 2 sapling and 4 seedlings species were found on highly disturbed site. The highest density for seedling was recorded for *Holarrhena pubescens* (3000 stems ha<sup>-1</sup>) followed by *Lagerstroemia parviflora* (2000 stems ha<sup>-1</sup>). The lowest seedling density (1000 stems ha<sup>-1</sup>) was recorded for *Milium tomentosum*. The only two saplings species found in the site was *Lagerstroemia parviflora* and *Holarrhena pubescens* (Table 4.1).

**Table 4.1 : Floristic composition and regeneration status on different sites**

Sr. No		Least Disturbed Site				Moderately Disturbed Site				Highly Disturbed Site			
		Tree (stems/ha)	Sapling (stems/ha)	Seedling (stems/ha)	Status	Tree (stems/ha)	Sapling (stems/ha)	Seedling (stems/ha)	Status	Tree (stems/ha)	Sapling (stems/ha)	Seedling (stems/ha)	Status
1	<i>Anogeissus latifolia</i>	10	-	-	No regeneration	10	-	-	No regeneration	10	-	-	No regeneration
2	<i>Bahuinia variegata</i>	-	-	250	Not abundant	-	-	-	-	-	-	-	-
3	<i>Boswellia serrata</i>	-	-	-	-	10	-	-	No regeneration	-	-	-	-
4	<i>Buchanania lanzan</i>	40	70	4500	Good regeneration	-	-	-	-	10	-	-	No regeneration
5	<i>Butea monosperma</i>	-	-	-	-	-	-	-	-	-	-	-	-
6	<i>Casearea graveolens</i>	-	-	250	Not abundant	-	80	1000	Not abundant	-	-	1750	Not abundant
7	<i>Cassia fistula</i>	-	-	-	-	10	-	-	No regeneration	-	-	-	-
8	<i>Cassine albeus</i>	-	-	250	Not abundant	-	-	250	Not abundant	-	-	-	-
9	<i>Chloroxylon swietenia</i>	-	-	-	-	10	20	1000	Good regeneration	-	-	-	-
10	<i>Cleistanthus collinus</i>	-	-	-	-	-	-	-	-	-	-	-	-
11	<i>Diospyros melanoxylon</i>	-	90	7000	Not abundant	10	30	-	No regeneration	-	-	-	-
12	<i>Ficus bengalensis</i>	10	-	-	No regeneration	-	-	-	-	-	-	-	-
13	<i>Flacourtia indica</i>	-	-	-	-	-	10	-	Poor regeneration	-	-	-	-
14	<i>Holarrhena pubescens</i>	-	-	-	-	100	250	19000	Good regeneration	-	10	3000	Not abundant
15	<i>Lagerstroemia parviflora</i>	-	-	-	-	90	160	2750	Good regeneration	10	20	2000	Good regeneration
16	<i>Lannea coromandelica</i>	-	-	500	Not abundant	20	10	-	No regeneration	10	-	-	No regeneration
17	<i>Madhuca latifolia</i>	130	130	6750	Good regeneration	10	-	-	No regeneration	-	-	-	-
18	<i>Miliusa tomentosa</i>	-	-	-	-	10	40	750	Good regeneration	-	-	1000	Not abundant
19	<i>Ougeinia ougeinensis</i>	10	-	-	No regeneration	-	-	-	-	-	-	-	-
20	<i>Pterocarpus marsupium</i>	-	10	750	Not abundant	-	-	-	-	-	-	-	-
21	<i>Schleichera oleosa</i>	-	-	-	-	-	-	750	Not abundant	-	-	-	-
22	<i>Semicarpus anacardium</i>	30	10	250	Fair regeneration	10	10	-	No regeneration	-	-	-	-
23	<i>Shorea robusta</i>	170	100	13500	Good regeneration	-	-	-	-	20	-	-	No regeneration
24	<i>Symplocos racemosa</i>	-	60	500	Not abundant	-	-	-	-	-	-	-	-
25	<i>Syzygium cumini</i>	60	10	4250	Fair regeneration	-	-	-	-	-	-	-	-
26	<i>Terminalia alata</i>	30	10	500	Fair regeneration	20	-	500	Poor regeneration	40	-	-	No regeneration
27	<i>Terminalia chebula</i>	20	-	250	Poor regeneration	-	-	-	-	-	-	-	-
<b>Total</b>		510	490	39500		310	610	26000		100	30	7750	

The three life stages (seedlings, saplings and trees) for different species suggested their possible future status in the forest. The density vs girth relationship between density and girth of the tree, sapling and seedling species on least disturbed and moderately disturbed site show consistent decrease from seedling to sapling stage (from <10 cm to 20–30 cm) and also from sapling to trees stage. While on highly disturbed site the density vs girth relationship between density and girth show decrease from seedling to sapling stage (from <10 cm to 20–30 cm), but from sapling to tree increased in density was observed (Fig. 4.2). This could be related to more biotic pressure on sapling population for the use as fuel wood and fodder. Thus, all the three forest sites were regenerating, although regeneration was higher on least disturbed site (Fig. 4.1).

The diameter distribution of trees has often been used to represent the population structure of forests (Saxena and Singh, 1984; Khan *et al.*, 1987a). In all the three forest site studied girth curve showed individuals with small girth class (<10 cm) were high followed by girth class (10–30 cm). Further, individuals with medium girth class (30–60 cm) were absent on highly disturbed site whereas the individuals with higher girth class (> 120 cm) were high on highly disturbed site as compared to moderately disturbed site and least disturbed site (Fig. 4.2). In a study conducted elsewhere the proportion of large diameter individuals was greater than small diameter individuals in the tree population in undisturbed stand while in the disturbed stand the proportion of young individuals was more (Khan *et al.*, 1987b).

In least disturbed site, out of 17 tree species, three species, viz., *Buchanania lanzan*, *Madhuca latifolia* and *Shorea robusta* showed good regeneration as all these species having good number of seedlings and saplings, three species recorded fair, one

species poor regeneration and seven were not abundant. Three species, viz., *Anogeissus latifolia*, *Ficus bengalensis* and *Ougeinia ougeinensis* were not regenerating. It might be due to thick litter accumulation which reduced seed germination of most canopy species (Janzen, 1970; Singh and Singh, 1992).

In moderately disturbed site, out of 16 tree species, four species, viz., *Chloroxylon swietenia*, *Holarrhena pubescens*, *Lagerstroemia parviflora* and *Miliusa tomentosa* showed good regeneration and none of the species showed fair while two species recorded poor regeneration and three were not abundant. Seven species were not found to be regenerating, viz., *Anogeissus latifolia*, *Boswellia serrata*, *Cassia fistula*, *Diospyros melanoxylon*, *Lannea coromandelica*, *Madhuca latifolia* and *Semicarpus anacardium* (Table 4.1).

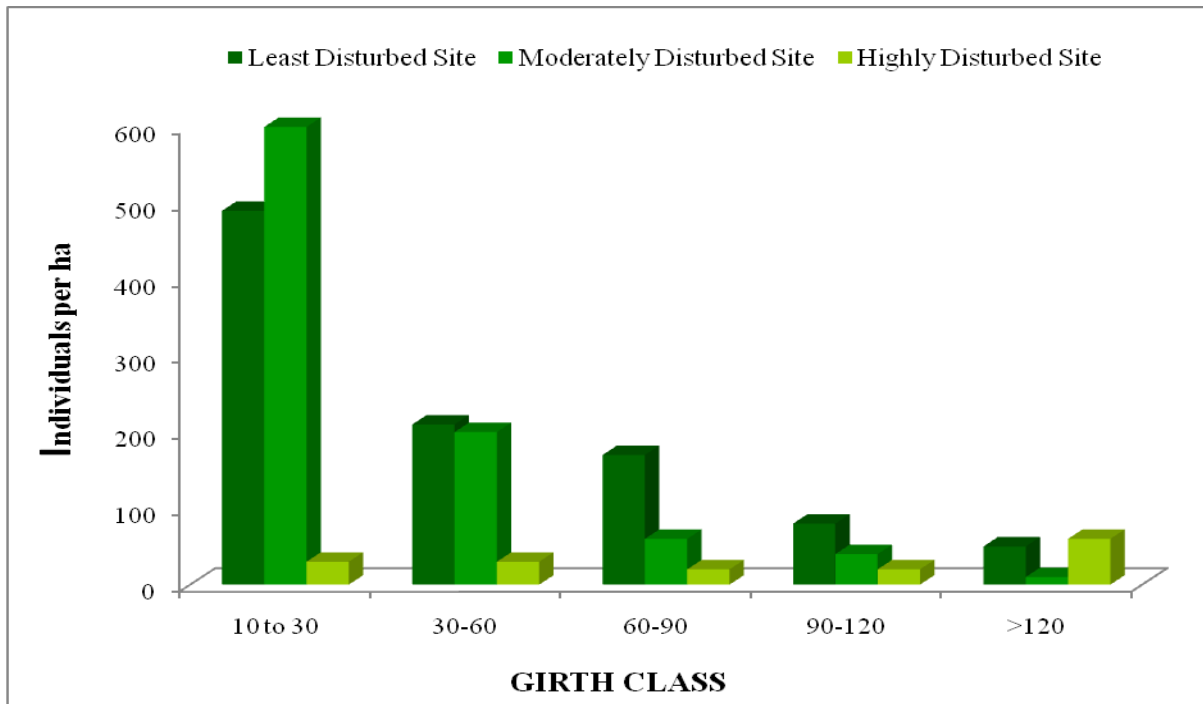
In highly disturbed site, out of 9 tree species, *Lagerstroemia parviflora* showed good regeneration and none of the species showed fair regeneration. Five species (*Anogeissus latifolia*, *Buchanania lanzan*, *Lannea coromandelica*, *Shorea robusta* and *Terminalia alata*) on this site were not found to be regenerating and three species were categorized as not abundant (Table 4.1). The population size of the species that lack either seedlings or saplings may decline in the coming years. The forest stands characterized by the abundance of only adults of the species or absence or very low population of seedlings and saplings are expected to face local extinction (Dalling *et al.*, 1998). Densities of seedlings are influenced by the densities of large trees (Rao *et al.*, 1990).

The density girth class distribution of tree species of least disturbed site and moderately disturbed site showed decline in density from seedlings (small diameter class) to saplings (higher diameter class) however highly disturbed site shows decline in density

from seedlings (small diameter class) to medium girth class but there was a further increase in population from medium girth class (60-120cm) to high girth class (>120cm) but the density of trees further declined in preceding girth classes. It shows that smaller diameter class individuals were high in number and only a small fraction of the seedlings and saplings classes survived to the larger tree classes (Fig. 4.3-4.5). A study on density–diameter distribution of woody species in the four sacred groves showed the highest stand density in the lowest girth class 30–60 cm (Kennedy *et al.*, 1991).

In all the three site least disturbed site was good regenerating because of high density of seedlings and saplings in forest site, however moderately disturbed site show comparatively better regeneration but highly disturbed site did not show good regeneration. Chauhan *et al.* (2008) found the species showing 32.5 % good regeneration, 19.8 % fair, 24.6 % poor and 11.1 % did not show regeneration out of 126 species in natural and planted forest in a Terai-Bhabhar forest in Katarnaighat Wildlife Sanctuary, India.

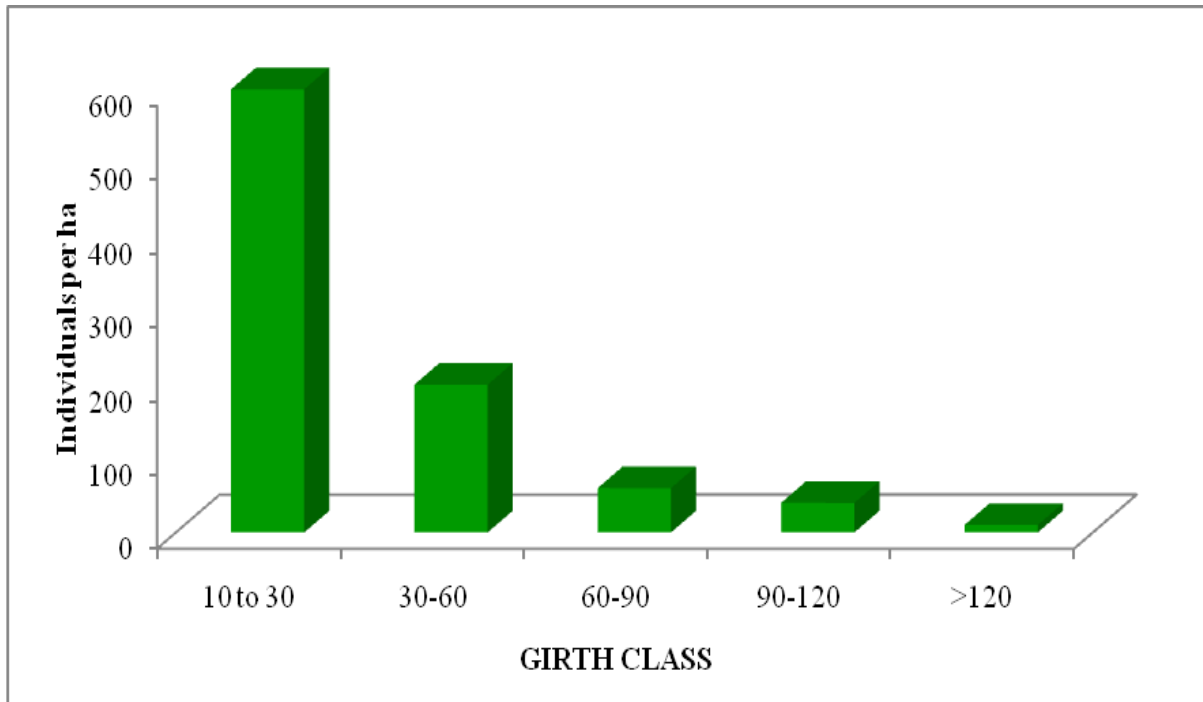
All the forest site does not comes under a protected area. Only least disturbed site was protected while lopping is allowed on moderately and highly disturbed site and thus the regeneration of species is severely affected by lopping, grazing and other anthropogenic pressure at both the site. Khurana (2007) concluded that biotic disturbances are making the site poor in nutrients and eroding top soil making the regeneration pattern inadequate. It has been recorded that regeneration of species is affected by fire (Sukumar *et al.*, 1997; Murthy *et al.*, 2002) grazing, light (Teketay, 1997), canopy density, soil moisture, soil nutrients and anthropogenic pressure. Regeneration of a species is dependent on internal forest process and exogenic



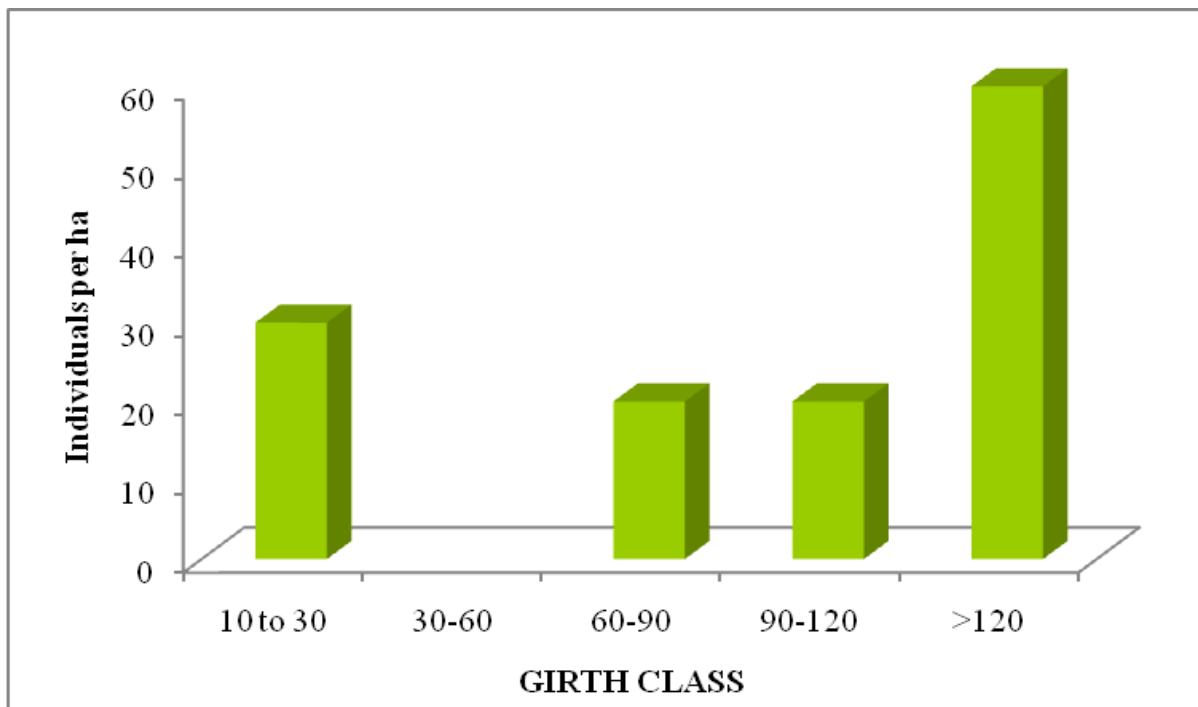
**Fig. 4.2: Relationship between density of seedling, sapling and trees with mean girth.** Girth classes (cm) are: 1 =  $\leq 10$  ; 2 =  $> 10 - \leq 30$  ; 3 =  $> 30 - \leq 60$  ; 4 =  $> 60 - \leq 90$  ; 5 =  $> 90 - \leq 120$  ; 6 =  $> 120$



**Fig. 4.3: Relationship between density of seedling, sapling and trees with mean girth in least disturbed site.** Girth classes (cm) are: 1 =  $\leq 10$  ; 2 =  $> 10 - \leq 30$  ; 3 =  $> 30 - \leq 60$  ; 4 =  $> 60 - \leq 90$  ; 5 =  $> 90 - \leq 120$  ; 6 =  $> 120$



**Fig. 4.4: Relationship between density of seedling, sapling and trees with mean girth in moderately disturbed site.** Girth classes (cm) are: 1 =  $\leq 10$  ; 2 =  $> 10 - \leq 30$  ; 3 =  $> 30 - \leq 60$  ; 4 =  $> 60 - \leq 90$  ; 5 =  $> 90 - \leq 120$  ; 6 =  $> 120$



**Fig. 4.5: Relationship between density of seedling, sapling and trees with mean girth in highly disturbed site.** Girth classes (cm) are: 1 =  $\leq 10$  ; 2 =  $> 10 - \leq 30$  ; 3 =  $> 30 - \leq 60$  ; 4 =  $> 60 - \leq 90$  ; 5 =  $> 90 - \leq 120$  ; 6 =  $> 120$

disturbance (Barker and Patrick, 1994). In the present study, three species on least disturbed site, five species on moderately disturbed site and seven species on highly disturbed site were not regenerating so it should be given emphasis in further research.

The Bartlett's test for the homogeneity of variation within different sites was not significant ( $p \leq 0.268$ ). Therefore, we may comfortably apply results of one way analysis of variance between the sites. The analysis of variation shows that the seedling density varied significantly ( $p \leq 0.000$ ) due to different levels of sites. The mean seedling density of highly disturbed site varied significantly with least and moderately disturbed site at 5% levels of significance while the mean seedling density of least and moderately disturbed site does not varied significantly.

Change in density and basal area of both seedling and sapling shows that anthropogenic disturbances were degrading forest year after year without any hope of rejuvenation without exclusion of these pressures.

## **4.2 Quantification of effect of protection on species diversity and species structure**

### **(Phytosociological analysis) on various forest sites**

#### **4.2.1 Species structure**

The biotic factors such as exploitation of forest to meet daily requirements of fuel wood, wood for agricultural implements and house construction, for preparation of boundaries along the houses and farm land, unregulated grazing by domestic cattle were the key determinants of structure and function of the forest. Variation in vegetation attributes such as IVI, tree density, basal area and distribution of the tree species on different sites in the forest indicate the complex plant succession resulting from varying degree of pressures on different sites.

#### 4.2.1.1 Least disturbed site:

In the least disturbed site a total of 510 trees ha<sup>-1</sup> representing 10 species were encountered. The overall density of tree layer was 510 stems ha<sup>-1</sup> followed by 490 stems ha<sup>-1</sup> and 39500 stems ha<sup>-1</sup> for sapling and seedling, respectively (Fig. 4.3). In tree layer, basal area and density of individual tree species varied from 0.11 m<sup>2</sup> ha<sup>-1</sup> to 11.47 m<sup>2</sup> ha<sup>-1</sup> and 10 to 170 stems ha<sup>-1</sup>, respectively. In sapling layer, basal area and density of individual tree species varied from 0.008 m<sup>2</sup> ha<sup>-1</sup> to 0.46 m<sup>2</sup> ha<sup>-1</sup> and 10 to 130 stems ha<sup>-1</sup>, respectively. The total basal area of tree layer on least disturbed site was 26.67 m<sup>2</sup> ha<sup>-1</sup>.

In tree layer, highest tree density was recorded for *Shorea robusta* (170 stems ha<sup>-1</sup>) followed by *Madhuca latifolia* (130 stems ha<sup>-1</sup>) and *Syzygium cumini* (60 stems ha<sup>-1</sup>). Lowest tree density (10 stems ha<sup>-1</sup>) was recorded for *Anogeissus latifolia*, *Ficus bengalensis* and *Ougeinia ougeinensis* (Table 4.2).

In tree layer, highest basal area was observed for *Shorea robusta* (11.47 m<sup>2</sup> ha<sup>-1</sup>) followed by *Syzygium cumini* (5.08 m<sup>2</sup> ha<sup>-1</sup>) and *Madhuca latifolia* (5.03 m<sup>2</sup> ha<sup>-1</sup>). Lowest basal area was observed for *Anogeissus latifolia* (0.11 m<sup>2</sup> ha<sup>-1</sup>). In sapling layer, highest basal area was observed for *Madhuca latifolia* (0.46 m<sup>2</sup> ha<sup>-1</sup>) followed by *Shorea robusta* (0.26 m<sup>2</sup> ha<sup>-1</sup>) and *Diospyros melanoxylon* (0.21 m<sup>2</sup> ha<sup>-1</sup>).

In tree layer (Table 4.2) *Shorea robusta* showed highest value of IVI (102.81) followed by *Madhuca latifolia* (67.91) and *Syzygium cumini* (39.66). In sapling layer (Table 4.3) *Madhuca latifolia* showed highest value of IVI (91.39) followed by *Shorea robusta* (55.50) and *Diospyros melanoxylon* (52.83). In seedling layer (Table 4.4) IVI was highest for *Shorea robusta* followed by *Syzygium cumini* and *Diospyros melanoxylon*.

**Table 4.2: Species structure of tree layer on different sites**

Sr. No.	Species	Least Disturbed Site				Moderately Disturbed Site				Highly Disturbed Site			
		F (%)	D (stems/ ha)	BA (m2/ha)	IVI	F (%)	D (stems/ha)	BA (m2/ha)	IVI	F (%)	D (stems/ha)	BA (m2/ha)	IVI
1	<i>Anogeissus latifolia</i>	10	10	0.11	5.34	10	10	1.09	16.73	10	10	0.76	25.21
2	<i>Bahuinia variegata</i>	-	-	-	-	-	-	-	-	-	-	-	-
3	<i>Boswellia serrata</i>	-	-	-	-	10	10	0.94	15.45	-	-	-	-
4	<i>Buchanania lanzan</i>	30	40	0.66	19.16	-	-	-	-	10	10	0.56	24.07
5	<i>Butea monosperma</i>	-	-	-	-	-	-	-	-	-	-	-	-
6	<i>Casearea graveolens</i>	-	-	-	-	-	-	-	-	-	-	-	-
7	<i>Cassia fistula</i>	-	-	-	-	10	10	0.17	8.75	-	-	-	-
8	<i>Cassine albeus</i>	-	-	-	-	-	-	-	-	-	-	-	-
9	<i>Chloroxylon swietenia</i>	-	-	-	-	10	10	0.09	8.04	-	-	-	-
10	<i>Cleistanthus collinus</i>	-	-	-	-	-	-	-	-	-	-	-	-
11	<i>Diospyrous melanoxyton</i>	-	-	-	-	10	10	0.22	9.26	-	-	-	-
12	<i>Ficus bengalensis</i>	10	10	0.10	5.27	-	-	-	-	-	-	-	-
13	<i>Flacourtia indica</i>	-	-	-	-	-	-	-	-	-	-	-	-
14	<i>Holarrhena pubescens</i>	-	-	-	-	70	100	1.64	74.62	-	-	-	-
15	<i>Lagerstroemiaparviflora</i>	-	-	-	-	60	90	1.44	65.64	10	10	0.55	23.78
16	<i>Lannea coromandelica</i>	-	-	-	-	20	20	1.73	29.59	10	10	1.38	29.02
17	<i>Madhuca latifolia</i>	80	130	5.03	67.91	-	-	-	-	-	-	-	-
18	<i>Miliusa tomentosa</i>	-	-	-	-	10	10	0.13	8.36	-	-	-	-
19	<i>Ougeinia ougeinensis</i>	10	10	0.45	6.41	10	10	0.39	10.67	-	-	-	-
20	<i>Pterocarpus marsupium</i>	-	-	-	-	-	-	-	-	-	-	-	-
21	<i>Schleichera oleosa</i>	-	-	-	-	-	-	-	-	-	-	-	-
22	<i>Semicarpus anacardium</i>	30	30	0.49	16.56	10	10	0.26	9.06	-	-	-	-
23	<i>Shorea robusta</i>	90	170	11.47	102.81	-	-	-	-	20	20	4.73	72.25
24	<i>Symplocos racemosa</i>	-	-	-	-	-	-	-	-	-	-	-	-
25	<i>Syzygium cumini</i>	30	60	5.08	39.66	-	-	-	-	-	-	-	-
26	<i>Terminalia alata</i>	30	30	1.39	19.95	20	20	3.36	43.83	40	40	6.70	125.67
27	<i>Terminalia chebula</i>	20	20	1.89	16.93	-	-	-	-	-	-	-	-
	TOTAL	340	510	26.67	300	250	310	11.46	300	100	100	14.67	300

\*F=Frequency , D = Density ,BA = Basal area, IVI=Importance value index

**Table 4.3: Species structure of sapling layer on different sites**

Sr. No.	Species	Least Disturbed Site				Moderately Disturbed Site				Highly Disturbed Site			
		F (%)	D (stems/ ha)	BA (m <sup>2</sup> /ha)	IVI	F (%)	D (stems/ha)	BA (m <sup>2</sup> /ha)	IVI	F (%)	D (stems/ha)	BA (m <sup>2</sup> /ha)	IVI
1	<i>Anogeissus latifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-
2	<i>Bahuinia variegata</i>	-	-	-	-	-	-	-	-	-	-	-	-
3	<i>Boswellia serrata</i>	-	-	-	-	-	-	-	-	-	-	-	-
4	<i>Buchanania lanzan</i>	50	70	0.15	40.90	-	-	-	-	-	-	-	-
5	<i>Butea monosperma</i>	-	-	-	-	-	-	-	-	-	-	-	-
6	<i>Casearea graveolens</i>	-	-	-	-	30	80	0.14	32.06	-	-	-	-
7	<i>Cassia fistula</i>	-	-	-	-	-	-	-	-	-	-	-	-
8	<i>Cassine albeus</i>	-	-	-	-	-	-	-	-	-	-	-	-
9	<i>Chloroxylon swietenia</i>	-	-	-	-	10	20	0.09	12.23	-	-	-	-
10	<i>Cleistanthus collinus</i>	-	-	-	-	-	-	-	-	-	-	-	-
11	<i>Diospyrous melanoxylon</i>	50	90	0.21	52.83	30	30	0.06	18.78	-	-	-	-
12	<i>Ficus bengalensis</i>	-	-	-	-	-	-	-	-	-	-	-	-
13	<i>Flacourtia indica</i>	-	-	-	-	10	10	0.02	5.86	-	-	-	-
14	<i>Holarrhena pubescens</i>	-	-	-	-	80	250	0.75	113.69	20	20	0.02	169.28
15	<i>Lagerstroemia parviflora</i>	-	-	-	-	90	160	0.39	80.28	10	10	0.04	130.72
16	<i>Lannea coromandelica</i>	-	-	-	-	10	10	0.01	5.86	-	-	-	-
17	<i>Madhuca latifolia</i>	80	130	0.46	91.39	-	-	-	-	-	-	-	-
18	<i>Miliusa tomentosa</i>	-	-	-	-	30	40	0.13	23.58	-	-	-	-
19	<i>Ougeinia ougeinensis</i>	-	-	-	-	-	-	-	-	-	-	-	-
20	<i>Pterocarpus marsupium</i>	10	10	0.02	7.34	-	-	-	-	-	-	-	-
21	<i>Schleichera oleosa</i>	-	-	-	-	-	-	-	-	-	-	-	-
22	<i>Semicarpus anacardium</i>	10	10	0.04	9.08	10	10	0.04	7.66	-	-	-	-
23	<i>Shorea robusta</i>	40	100	0.26	55.5	-	-	-	-	-	-	-	-
24	<i>Symplocos racemosa</i>	30	60	0.09	30.4	-	-	-	-	-	-	-	-
25	<i>Syzygium cumini</i>	10	10	0.008	6.14	-	-	-	-	-	-	-	-
26	<i>Terminalia alata</i>	-	-	-	-	-	-	-	-	-	-	-	-
27	<i>Terminalia chebula</i>	10	10	0.01	6.42	-	-	-	-	-	-	-	-
<b>TOTAL</b>		290	490	1.24	300	300	610	1.63	300	30	30	0.06	300

\*F=Frequency, D = Density, BA = Basal area, IVI=Importance value index

**Table 4.4: Species structure of seedling layer on different sites**

Sr. No.	Species	Least Disturbed Site				Moderately Disturbed Site				Highly Disturbed Site			
		F (%)	D (stems/ha)	AB	IVI	F (%)	D (stems/ha)	AB	IVI	F (%)	D (stems/ha)	AB	IVI
1	<i>Anogeissus latifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-
2	<i>Bahuinia variegata</i>	10	250	10	5.22	-	-	-	-	-	-	-	-
3	<i>Boswellia serrata</i>	-	-	-	-	-	-	-	-	-	-	-	-
4	<i>Buchanania lanzan</i>	50	4500	36	31.32	-	-	-	-	-	-	-	-
5	<i>Butea monosperma</i>	-	-	-	-	-	-	-	-	-	-	-	-
6	<i>Casearea graveolens</i>	10	250	10	5.22	30	1000	13.33	23.88	30	1750	23.33	66.86
7	<i>Cassia fistula</i>	-	-	-	-	-	-	-	-	-	-	-	-
8	<i>Cassine albeus</i>	10	250	10	5.22	10	250	10	9.74	-	-	-	-
9	<i>Chloroxylon swietenia</i>	-	-	-	-	10	1000	40	23.97	-	-	-	-
10	<i>Cleistanthus collinus</i>	-	-	-	-	-	-	-	-	-	-	-	-
11	<i>Diospyrous melanoxylon</i>	90	7000	31.11	46.36	-	-	-	-	-	-	-	-
12	<i>Ficus bengalensis</i>	-	-	-	-	-	-	-	-	-	-	-	-
13	<i>Flacourtia indica</i>	-	-	-	-	-	-	-	-	-	-	-	-
14	<i>Holarrhena pubescens</i>	-	-	-	-	90	19000	84.44	150.00	60	3000	20	103.04
15	<i>Lagerstroemia parviflora</i>	-	-	-	-	30	2750	36.66	39.44	30	2000	26.66	73.12
16	<i>Lannea coromandelica</i>	10	500	20	8.00	-	-	-	-	-	-	-	-
17	<i>Madhuca latifolia</i>	50	6750	54	40.89	-	-	-	-	-	-	-	-
18	<i>Miliusa tomentosa</i>	-	-	-	-	10	750	30	19.27	10	1000	40	56.93
19	<i>Ougeinia ougeinensis</i>	-	-	-	-	-	-	-	-	-	-	-	-
20	<i>Pterocarpus marsupium</i>	30	750	10	11.36	-	-	-	-	-	-	-	-
21	<i>Schleichera oleosa</i>	-	-	-	-	10	750	30	19.22	-	-	-	-
22	<i>Semicarpus anacardium</i>	10	250	10	5.22	-	-	-	-	-	-	-	-
23	<i>Shorea robusta</i>	100	13500	54	70.17	-	-	-	-	-	-	-	-
24	<i>Symplocos racemosa</i>	10	500	20	8.00	-	-	-	-	-	-	-	-
25	<i>Syzygium cumini</i>	10	4250	170	49.74	-	-	-	-	-	-	-	-
26	<i>Terminalia alata</i>	10	500	20	8.00	10	500	20	14.48	-	-	-	-
27	<i>Terminalia chebula</i>	10	250	10	5.28	-	-	-	-	-	-	-	-
	Total	410	39500	465.11	300.00	200	26000	264.44	300	130	7750	110	300

\*F=Frequency, D = Density, AB = Abundance, IVI=Importance value index

In the least disturbed site out of total trees (640 stems ha<sup>-1</sup>) 20.31 per cent trees (130 stems ha<sup>-1</sup>) were found to be lopped and 79.69 per cent trees (510 stems ha<sup>-1</sup>) found unlopped representing density as 510 trees ha<sup>-1</sup> excluding lopped trees (Fig. 4.6).

#### **4.2.1.2 Moderately disturbed site:**

In the moderately disturbed site a total of 310 trees ha<sup>-1</sup> representing 16 species were encountered. The overall density of tree layer was 310 stems ha<sup>-1</sup> followed by 610 stems ha<sup>-1</sup> and 26000 stems ha<sup>-1</sup> for sapling and seedling, respectively (Fig. 4.4). In tree layer, basal area and density of individual tree species varied from 0.09 m<sup>2</sup> ha<sup>-1</sup> to 3.36 m<sup>2</sup> ha<sup>-1</sup> and 10 to 100 stems ha<sup>-1</sup>, respectively. In sapling layer, basal area and density of individual tree species varied from 0.01 m<sup>2</sup> ha<sup>-1</sup> to 0.75 m<sup>2</sup> ha<sup>-1</sup> and 10 to 250 stems ha<sup>-1</sup>, respectively. The total basal area of tree on moderately disturbed site was 11.46 m<sup>2</sup> ha<sup>-1</sup>.

In tree layer, highest tree density was recorded for *Holarrhena pubescens* (100 stems ha<sup>-1</sup>) followed by *Lagerstroemia parviflora* (90 stems ha<sup>-1</sup>). Lowest tree density (10 stems ha<sup>-1</sup>) was recorded for *Anogeissus latifolia*, *Boswellia serrata*, *Cassia fistula*, *Chloroxylon swietenia*, *Diospyros melanoxylon*, *Miliusa tomentosa*, *Ougeinia ougeinensis* and *Semicarpus anacardium* (Table 4.2).

In tree layer, highest basal area was observed for *Terminalia alata* (3.36 m<sup>2</sup> ha<sup>-1</sup>) followed by *Lannea coromandelica* (1.73 m<sup>2</sup> ha<sup>-1</sup>) and *Holarrhena pubescens* (1.64 m<sup>2</sup> ha<sup>-1</sup>). Lowest basal area was observed for *Miliusa tomentosa* (0.13 m<sup>2</sup> ha<sup>-1</sup>). In sapling layer, highest basal area was observed for *Holarrhena pubescens* (0.75 m<sup>2</sup> ha<sup>-1</sup>) followed by *Lagerstroemia parviflora* (0.39 m<sup>2</sup> ha<sup>-1</sup>) and *Casearea graveolens* (0.14 m<sup>2</sup> ha<sup>-1</sup>).

In tree layer (Table 4.2) *Holarrhena pubescens* showed highest value of IVI (74.62) followed by *Lagerstroemia parviflora* (65.64) and *Terminalia alata* (43.83). In

sapling layer (Table 4.3) *Holarrhena pubescens* showed highest value of IVI (113.69) followed by *Lagerstroemia parviflora* (80.28) and *Casearia graveolens* (32.06). In seedling layer (Table 4.4) IVI was highest for *Holarrhena pubescens* followed by *Lagerstroemia parviflora* and *Casearia graveolens*.

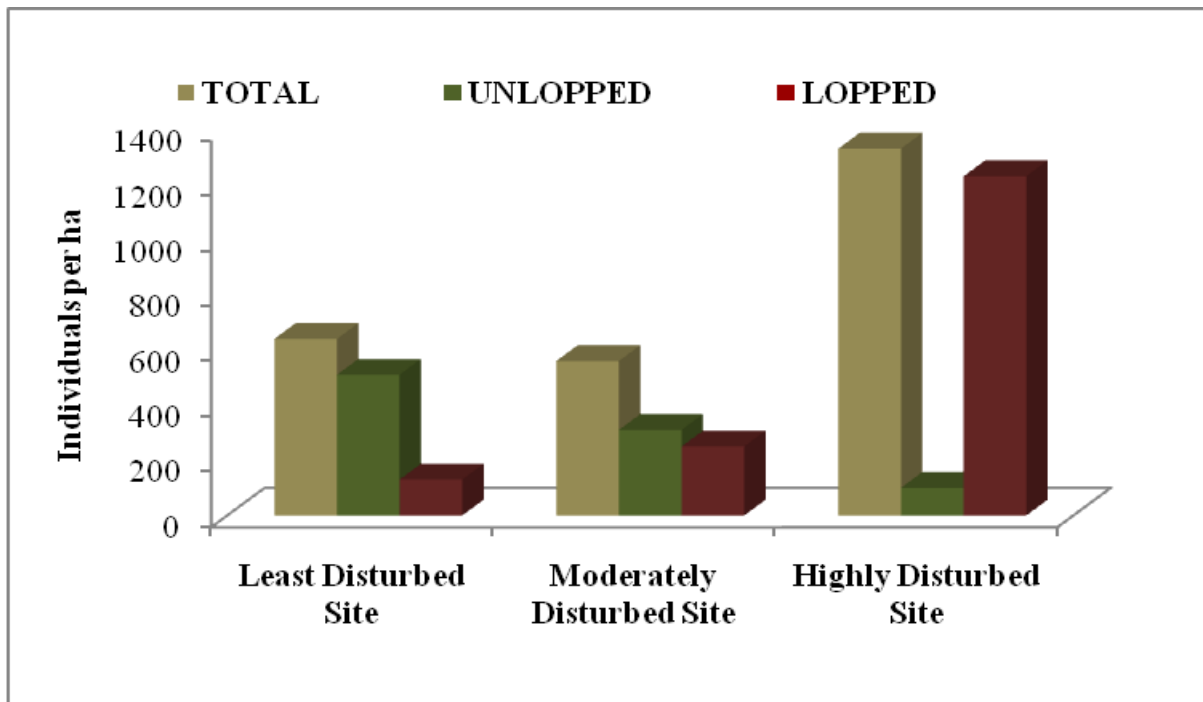
In the moderately disturbed site out of total trees (560 stems ha<sup>-1</sup>) 44.64 per cent trees (250 stems ha<sup>-1</sup>) were found to be lopped and 55.36 per cent trees found unlopped (310 stems ha<sup>-1</sup>) representing density as 310 trees ha<sup>-1</sup> excluding lopped trees (Fig. 4.6)..

#### 4.2.1.3 Highly disturbed site:

In the highly disturbed site a total of 100 trees ha<sup>-1</sup> representing 9 species were encountered. The overall density of tree layer was 100 stems ha<sup>-1</sup> followed by 30 stems ha<sup>-1</sup> and 7750 stems ha<sup>-1</sup> for sapling and seedling, respectively (Fig. 4.5). In tree layer, basal area and density of individual tree species varied from 0.55 m<sup>2</sup> ha<sup>-1</sup> to 6.70 m<sup>2</sup> ha<sup>-1</sup> and 10 to 40 stems ha<sup>-1</sup>, respectively. In sapling layer, basal area and density of individual tree species varied from 0.02 m<sup>2</sup> ha<sup>-1</sup> to 0.04 m<sup>2</sup> ha<sup>-1</sup> and 10 to 20 stems ha<sup>-1</sup>, respectively. The total basal area of tree on highly disturbed site was 14.67 m<sup>2</sup> ha<sup>-1</sup>.

In tree layer, highest tree density was recorded for *Terminalia alata* (40 stems ha<sup>-1</sup>) followed by *Shorea robusta* (20 stems ha<sup>-1</sup>). Lowest tree density (10 stems ha<sup>-1</sup>) was recorded for *Anogeissus latifolia*, *Buchanania lanzan*, *Lannea coromandalica* and *Lagerstroemia parviflora*.

In tree layer, highest basal area was observed for *Terminalia alata* (6.70 m<sup>2</sup> ha<sup>-1</sup>) followed by *Shorea robusta* (4.73 m<sup>2</sup> ha<sup>-1</sup>) and *Lannea coromandalica* (1.38 m<sup>2</sup> ha<sup>-1</sup>). Lowest basal area was observed for *Lagerstroemia parviflora* (0.55 m<sup>2</sup> ha<sup>-1</sup>). In sapling



**Fig. 4.6: Distribution of lopped and unlopped trees on different sites.**

layer, highest basal area was observed for *Lagerstroemia parviflora* ( $0.04 \text{ m}^2 \text{ ha}^{-1}$ ) followed by *Holarrhena pubescens* ( $0.02 \text{ m}^2 \text{ ha}^{-1}$ ).

In tree layer (Table 4.2) *Terminalia alata* showed highest value of IVI (125.67) followed by *Shorea robusta* (72.25) and *Lannea coromandelica* (29.07). In sapling layer (Table 4.3) *Holarrhena pubescens* showed highest value of IVI (169.28) followed by *Lagerstroemia parviflora* (130.72). In seedling layer (Table 4.4) IVI was highest for *Holarrhena pubescens* followed by *Lagerstroemia parviflora* and *Casearea graveolens*.

In the highly disturbed site out of total trees ( $1330 \text{ stems ha}^{-1}$ ) 92.48 per cent trees ( $1230 \text{ stems ha}^{-1}$ ) were found to be lopped and 7.52 per cent trees ( $100 \text{ stems ha}^{-1}$ ) found unlopped representing density as  $100 \text{ trees ha}^{-1}$  excluding lopped trees (Fig. 4.6).

The Bartlett's test for the homogeneity of variation for sapling density ( $p \leq 0.402$ ) and basal area ( $p \leq 0.707$ ) within different sites was not significant whereas, for tree density ( $p \leq 0.0001$ ) was significant. The analysis of variation for the sapling density ( $p \leq 0.000$ ) and basal area ( $p \leq 0.003$ ) shows that there was highly significant difference due to different levels of sites. The mean sapling density of least and moderately disturbed site does not varied significantly while, the mean sapling density of highly disturbed site varied significantly with moderately and least disturbed site at 5% levels of significance. The mean basal area of least and highly disturbed site does not varied significantly while, the mean basal area of least and highly disturbed site varied significantly with moderately disturbed site at 5% levels of significance.

Tree basal cover in the present study varied from  $11.46$  to  $26.67 \text{ m}^2 \text{ ha}^{-1}$  on three different sites. These basal cover values were higher than the values reported for several dry tropical forest communities in Western India reported by Kumar *et al.* (2010) with

average basal area ranging from 5.96 - 19.31 m<sup>2</sup> ha<sup>-1</sup>. The basal area in tropical dry deciduous forest was 3.80 to 10.36 m<sup>2</sup> ha<sup>-1</sup> (Singh and Singh, 1991) and was 18.09 m<sup>2</sup> ha<sup>-1</sup> in tropical dry deciduous forest of Bhadra wildlife sanctuary (Krishnamurthy *et al.*, 2010). Basal cover in a Puerto Rican sub-tropical dry forest was 19.8 m<sup>2</sup> ha<sup>-1</sup> (Murphy and Lugo, 1986b) and of sal forest in Tripura was between 2.33 and 86.29 m<sup>2</sup> ha<sup>-1</sup> (Rastogi and Rastogi, 2007). These values compare with Vindhyan region reported by Jha and Singh (1990) between 6.58 and 23.21 m<sup>2</sup> ha<sup>-1</sup> and 26.3 m<sup>2</sup> ha<sup>-1</sup> in sal dominated forest of eastern Himalaya (Shankar, 2001).

Khatri (2000) reported total basal area at Satpura National park (M.P.) between 17.37 and 26.28 m<sup>2</sup> ha<sup>-1</sup>. Ilorkar and Khatri (2003) at Navegaon National park observed total basal area was between 14.15 and 17.21 m<sup>2</sup> ha<sup>-1</sup>. Quigley and Platt (2003) reported mean basal area from 17.7 to 48.021 m<sup>2</sup> ha<sup>-1</sup> at seasonally deciduous forest of America. The basal cover values of present study were less than the values between 8.15 and 41.17 m<sup>2</sup> ha<sup>-1</sup> reported for Achanakmar-Amarkantak biosphere reserve in central India by Sahu *et al.* (2008). However, Rodgers (1990) reported a very high value of basal cover (131 m<sup>2</sup> ha<sup>-1</sup>) for the forests of Sariska Tiger Reserve (Table 4.5).

In the present study, tree density ranged between 100 and 510 stems ha<sup>-1</sup> on three different sites. These tree density values were higher than 484 stems ha<sup>-1</sup> reported for sal dominated forest of eastern Himalaya by Shankar (2001); 82 to 468 stems ha<sup>-1</sup> reported for moist deciduous forest by Upadhyay *et al.* (2008). The density of present study was within the range of 554 to 789 stems ha<sup>-1</sup> reported in dry *Dipterocarp* forest (Visaratana *et al.*, 1986); of 458-728 stems ha<sup>-1</sup> reported in tropics (Sundarapandian and Swamy, 2000) and of 575-855 stems ha<sup>-1</sup> for Kalakad, Western Ghat (Parthasarthy, 1999).

**Table 4.5: Certain vegetational properties of tropical forest**

<b>Forest Ecosystems</b>	<b>Density (stems ha<sup>-1</sup>)</b>	<b>Basal cover (m<sup>2</sup> ha<sup>-1</sup>)</b>	<b>Number of species Per ha.</b>	<b>Source</b>
Mixed deciduous forest	394-539	6.6-23.2	-	Jha and Singh (1990)
<i>Boswellia-Acacia</i> forest	342-627	3.8-10.4	-	Singh (1991), Singh and Singh (1991).
Mixed Sal forest	558-1744	15.0-31.5	-	Sharma <i>et al.</i> (1990)
Pure Sal forest	386-785	12.7-33.2	-	Sharma <i>et al.</i> (1990)
Sariska Tiger Reserve	1352	131.9	-	Rodgers (1990)
Sal dominated closed forest	1220-1290	25.4-44.65	15-22*	Singh <i>et al.</i> (2003)
Sal dominated open forest	390-930	20.05-45.89	11-16*	Singh <i>et al.</i> (2003)
Dry Dipterocarp forest	554-789	-	35-37	Visaratana <i>et al.</i> (1986)
Mixed deciduous forest	253	-	14	Sahunalu <i>et al.</i> (1979), Kiratiprayoon <i>et al.</i> (1995)
Seasonally dry tropical forest	484	26.3	-	Sahu <i>et al.</i> (2008)
Tropical dry deciduous	458-728	5.96-19.31	-	Kumar <i>et al.</i> (2010)
Tropical dry deciduous	883	18.09	-	Krishnamurthy <i>et al.</i> (2010)
Tropical rain forest	818-1540	-	61-109	Kiratiprayoon (1986)
Tropical moist deciduous	448-1217	21.43-34.05	31-59	Bhat <i>et al.</i> (2000)
Tropical moist deciduous	82-468	6.8-62.2	-	Upadhyay <i>et al.</i> (2008)
	100-510	11.46-26.67	-	Present study

\*Represents the number of species in 0.1 ha.

Compared to the present study the density of forest in Thailand, of mixed deciduous forest was 253 stems ha<sup>-1</sup> (Sahunalu *et al.*, 1979) and of tropical rain forest was 818 to 1540 stems ha<sup>-1</sup> (Kiratiprayoon, 1986). Tree density in the Vindhyan region ranges between 294 and 627 stems ha<sup>-1</sup> for several dry tropical forest communities (Singh and Singh, 1991; Jha and Singh, 1990). The forest canopy was three storied in the present forest. The dry tropical forest usually has 1-3 and the wet tropical forest three or more canopy strata (Murphy and Lugo, 1986a). Density and basal cover values in the forests of the study area are compared with the forest of Vindhyan hills and other tropical forests studied elsewhere. In general the above values are comparable to the several tropical forests.

#### **4.2.2 Species diversity**

Species diversity, the number of species in a community is ecologically important, since it seems to increase as more stable community. The valuations of species diversity on different sites of same locality is not a good sign for better growth of forest of any area. Diversity parameters on different forest site is given in Table 4.6

##### **4.2.2.1 Species richness (d)**

Species richness for tree layer varies from (1.08) for highly disturbed site to (1.91) for moderately disturbed site. In tree layer species richness was highest (1.91) on moderately disturbed site followed by least disturbed site (1.44) and lowest on highly disturbed site (1.08). Species richness for seedling layer was highest (1.23) on least disturbed site followed by moderately disturbed site (0.68) and lowest on highly disturbed site (0.33) (Table 4.6). Species richness for sapling layer varies from (1.29) for least disturbed site to (0.29) for highly disturbed site. Mishra *et al.* (2004) described a

higher value for Shannon index and Species richness for moderately disturbed site in a Sacred grove in Meghalaya, N.E India.

#### **4.2.2.2 Shannon index ( $H'$ )**

In tree layer Shannon index ( $H'$ ) value was 2.68 on least disturbed site, 2.83 on moderately disturbed site and 2.32 on highly disturbed site, respectively. In sapling layer Shannon index ( $H'$ ) value was 2.65 on least disturbed site, 2.34 on moderately disturbed site and 0.91 on highly disturbed site, respectively. In seedling layer Shannon index ( $H'$ ) value was 2.68 on least disturbed site, 1.50 on moderately disturbed site and 1.90 on highly disturbed site, respectively. In all three sites the species diversity for tree layer was highest on moderately disturbed site whereas for sapling and seedling layer was highest on least disturbed site.

#### **4.2.2.3 Concentration of dominance ( $C_d$ )**

In the forest under study highest  $C_d$  value for tree layer was on highly disturbed site followed by moderately disturbed site and least disturbed site. The  $C_d$  values for tree layer were 0.20, 0.20 and 0.24, respectively for least, moderately and highly disturbed site. The  $C_d$  values for sapling layer were 0.18, 0.26 and 0.55, respectively for least, moderately and highly disturbed site. The  $C_d$  values for seedling layer were 0.20, 0.55 and 0.28, respectively for least, moderately and highly disturbed site (Table 4.6). In the seedling layer  $C_d$  value was highest on moderately disturbed site followed by highly disturbed and least disturbed site.

#### **4.2.2.4 Equitability ( $e$ )**

Equitability ( $e$ ) for tree layer was 1.16 for least disturbed site, 1.13 for moderately disturbed site and 1.29 for highly disturbed site; for sapling layer it was 1.20 for least

**Table 4. 6: Diversity parameters of various forest sites**

Natural Parameters	Least Disturbed Site	Moderately Disturbed Site	Highly Disturbed Site	Least Disturbed Site	Moderately Disturbed Site	Highly Disturbed Site	Least Disturbed Site	Moderately Disturbed Site	Highly Disturbed Site
	<b>TREE LAYER</b>			<b>SAPLING LAYER</b>			<b>SEEDLING LAYER</b>		
Species richness (d)	1.44	1.91	1.08	1.29	1.24	0.29	1.23	0.68	0.33
Shannon index (H')	2.68	2.83	2.32	2.65	2.34	0.91	2.68	1.50	1.90
Concentration of dominance (Cd)	0.20	0.20	0.24	0.18	0.26	0.55	0.20	0.55	0.28
Equitability (e)	1.16	1.13	1.29	1.20	1.06	1.31	1.01	0.72	1.37
Beta diversity (Bd)	1.80	1.50	3.00	1.77	1.77	8.00	1.35	2.37	4.75

disturbed site, 1.06 for moderately disturbed site and 1.31 for highly disturbed site; while for seedling layer it was 1.01 for least disturbed site, 0.72 for moderately disturbed site and 1.37 for highly disturbed site (Table 4.6). The values of Equitability (e) for tree layer was highest on highly disturbed site followed by least disturbed site and lowest at moderately disturbed site. Sapling and seedling layer also followed the similar trend as tree layer.

#### **4.2.2.5 Beta diversity**

Beta diversity for the forest was highest on highly disturbed site in all layers, respectively (3.00 for tree layer, 8.00 sapling layer and 4.75 for seedling layer). Beta diversity for the forest under study was 1.80, 1.50 and 3.00 (Table 4.6), for tree layer on least disturbed, moderately disturbed and highly disturbed site, respectively; for sapling layer was 1.77, 1.77 and 8.00 and for seedling layer was 1.35, 2.37 and 4.75 on least disturbed, moderately disturbed and highly disturbed site. Beta diversity for tree layer was highest on highly disturbed site 3.00 followed by 1.80 least disturbed and 1.50 moderately disturbed site.

Results of diversity parameter revealed that the Shannon index values for tree layer in different forest sites ranged from 2.32 to 2.83, Cd value from 0.20 to 0.24 and beta diversity from 1.50 to 3.00. Species richness for tree layer in present study varies from 1.08 to 1.91. Arunachalam (2002) reported species richness index as 2.73 in dry tropical forest while 2.32 in wet evergreen forest of Western Ghats. Tripathi *et al.* (2004) reported richness index from 2.25 to 3.94 in humid tropical evergreen forests of Andaman Island while it was between 1.10 and 1.15 in forests of Andaman Island (Tripathi *et al.*, 2006). The Shannon index values for tree layer in present study are

comparable with the Shannon index values 2.20-2.65 reported for tropical forests of Western Ghat (Sundarapandian and Swamy, 2000), 2.65-2.94 for Western Ghat (Arunachalam, 2002) and 2.09-3.06 for Anaikatty hills, Western Ghats by Anitha *et al.* (2007).

The Shannon index values for tree species was lower than value 3.9 reported for Sal forests of Eastern Himalaya (Shankar, 2001) and 3.53 for old sal plantations in Gorakhpur (Shukla and Pandey, 2000). Panchal and Pandey (2004) observed Shannon index value as 2.03 and 3.53, respectively in tropical forests in Gujrat and sal forest in North India. Tripathi (2001) reported Shannon index value ranging between 3.25 and 3.99 for a rehabilitated tropical forest in North India.

The Shannon index of dry tropical forests in study area was comparatively lower than those reported by Singh *et al.* (1984). Singh *et al.* (1984) reported Shannon index value between 3.4 and 4.8 for tropical rain forests of Silent valley in Western Ghats, India. Similarly, the lower diversity of moist tropical ecosystem in this study is attributed to sharing of large proportion of resources to only few species, while in tropical evergreen forests more number of species efficiently shared the resources. Therefore, the higher diversity was found in those forests. It is also evident from the results that Shannon index values were higher than concentration of dominance for different site of forest. The inverse relationship was found between Shannon index and Simpson index. These results are in agreement with earlier findings of Singh and Singh (1991) and Kumar *et al.* (2010).

Among different forest sites, the least disturbed site showed higher diversity and lower dominance, while highly disturbed site showed poor diversity and higher

concentration of dominance. The higher diversity in least disturbed site is attributed to the presence of higher number of species (17), while the higher concentration of dominance in highly disturbed site were attributed to higher relative proportion of *Terminalia alata* in these forest types compared to other species.

The beta diversity was found to be highest for highly disturbed site and lowest for moderately disturbed site, shows that higher rate of species turnover in former type compared to other forest type. The higher beta diversity represents the higher niche diversification in highly disturbed site compared to moderately disturbed site and least disturbed site. The results also showed that disturbance significantly influenced the basal area, tree density and species diversity, concentration of dominance and beta diversity in the forest.

#### **4.3 Quantification of effect of protection on biomass pattern on various forest sites**

The Bartlett's test in case of biomass was significant at 5% level, this violates the basic assumption of homogeneity of variances of sites for analysis of variance. When the reason was traced it was observed that the highly disturbed site coincidentally contained nearly equal quantity of biomass, due to which the variability within site (highly disturbed site) was almost negligible, which forced the heterogeneity of variances among all the sites, which includes highly disturbed site too.

It may be noted here that the site variances should be homogeneous before going for analysis of variance of the sites. This is tested by the Bartlett's test. Thus, this problem is not that of the sites, rather it is a coincidental problem in which all the quadrats have similar values. On a larger canvass the quadrat's constituent may not be the same. Therefore, although technically we cannot proceed, having given this caution, we

are still proceeding to have an idea about the significance of difference due to sites on the biomass, whose F-test turns out to be non-significant at the 5% level of significance.

Total biomass in the present study was between 127.69 t ha<sup>-1</sup> and 227.71 t ha<sup>-1</sup>. It was highest on least disturbed site (227.71 t ha<sup>-1</sup>) followed by highly disturbed site (183.20 t ha<sup>-1</sup>) and lowest on moderately disturbed site (127.69 t ha<sup>-1</sup>). Total above ground biomass was between 110.99 t ha<sup>-1</sup> and 199.41 t ha<sup>-1</sup> and total below ground biomass was between 16.49 t ha<sup>-1</sup> and 28.29 t ha<sup>-1</sup>, respectively. Total litter biomass in the present study was between 2.75 t ha<sup>-1</sup> and 3.55 t ha<sup>-1</sup>. The litter biomass value was highest on least disturbed site (3.55 t ha<sup>-1</sup>) followed by moderately disturbed site (3.46 t ha<sup>-1</sup>) and lowest on highly disturbed site (2.75 t ha<sup>-1</sup>; Fig. 4.10).

#### **4.3.1 Least disturbed site:**

The total biomass for least disturbed site (Table 4.7) was 227.71 t ha<sup>-1</sup> of which 199.41 t ha<sup>-1</sup> was above ground and 28.29 t ha<sup>-1</sup> was below ground biomass. The distribution of biomass in the different components was 117.25 t ha<sup>-1</sup> in bole, 74.84 t ha<sup>-1</sup> in branch, 7.32 t ha<sup>-1</sup> in leaf and 28.29 t ha<sup>-1</sup> in root. The bole, branch, leaf and root constitute about 51.49, 32.86, 3.21 and 12.42 per cent, respectively of the total biomass. Among the individual species *Shorea robusta* constitutes the highest biomass (110.31) followed by *Madhuca latifolia* (43.70) and *Syzygium cumini* (30.82), which contributed 48.44, 19.19 and 13.53 per cent of the total biomass.

The total litter biomass was 3.55 t ha<sup>-1</sup> (Table 4.8). The distribution of biomass in the different components was 2.38 t ha<sup>-1</sup> in fresh leaf litter, 0.70 t ha<sup>-1</sup> in wood litter and 0.46 t ha<sup>-1</sup> in partially decomposed litter (Fig. 4.12). The fresh leaf litter, wood litter and

**Table 4.7: Biomass (t ha<sup>-1</sup>) of different tree component on different sites**

S.No	Species	Least Disturbed Site					Moderately Disturbed Site					Highly Disturbed Site				
		Branch	Bole	Leaf	Root	Total	Branch	Bole	Leaf	Root	Total	Branch	Bole	Leaf	Root	Total
1	<i>Anogeissus latifolia</i> Roxb. ex DC	-	-	-	-	-	2.74	11.71	0.66	2.13	17.25	1.84	6.99	0.41	1.38	10.64
2	<i>Boswellia serrata</i> Roxb. ex Colebr	-	-	-	-	-	2.83	4.54	0.27	1.06	8.70	-	-	-	-	-
3	<i>Buchanania lanzan</i> Spreng	1.53	0.87	0.22	0.48	3.11	-	-	-	-	-	1.52	2.11	0.21	0.44	4.28
4	<i>Casearea graveolens</i> Dalz	-	-	-	-	-	0.26	0.11	0.04	0.09	0.52	-	-	-	-	-
5	<i>Cassia fistula</i> Linn	-	-	-	-	-	0.40	0.37	0.04	0.15	0.98	-	-	-	-	-
6	<i>Chloroxylon sweitenia</i> DC	-	-	-	-	-	0.36	0.26	0.04	0.13	0.81	-	-	-	-	-
7	<i>Cleistanthus collinus</i> Roxb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	<i>Diospyros melanoxylon</i> Roxb	0.32	0.11	0.04	0.41	0.90	0.73	0.55	0.06	0.47	1.84	-	-	-	-	-
9	<i>Ficus bengalensis</i> L.	0.22	0.17	0.02	0.08	0.50	-	-	-	-	-	-	-	-	-	-
10	<i>Flacourtia indica</i> Burm.f.	-	-	-	-	-	0.03	0.01	0.01	0.01	0.06	-	-	-	-	-
11	<i>Holarrhena pubescens</i> (Buchi.Ham)	-	-	-	-	-	3.99	2.74	0.70	1.55	8.98	0.05	0.04	0.01	0.03	0.13
12	<i>Lagerstroemia parviflora</i> Roxb.	-	-	-	-	-	5.53	4.92	0.76	2.65	13.88	1.65	1.78	0.20	0.91	4.55
13	<i>Lannea coromandelica</i> Houtt.	-	-	-	-	-	5.73	9.32	0.53	2.15	17.75	4.21	7.59	0.38	1.58	13.77
14	<i>Madhuca indica</i> J.F. Gmel	15.63	20.58	1.61	5.86	43.70	-	-	-	-	-	-	-	-	-	-
15	<i>Miliusa tomentosa</i> Roxb.	-	-	-	-	-	0.40	0.48	0.07	0.22	1.40	-	-	-	-	-
16	<i>Ougeinia oojeinensis</i> Roxb.	-	-	-	-	-	1.31	1.68	0.13	0.49	3.62	-	-	-	-	-
17	<i>Pterocarpus marsupium</i> Roxb	0.03	0.01	0.01	0.01	0.05	-	-	-	-	-	-	-	-	-	-
18	<i>Semecarpus anacardium</i> Linn. f	1.38	1.30	0.16	0.51	3.36	0.75	0.74	0.08	0.28	1.86	-	-	-	-	-
19	<i>Shorea robusta</i> Roxb.ex Gaertn.f.	33.89	60.55	3.13	12.73	110.31	-	-	-	-	-	17.24	38.34	1.43	6.48	63.52
20	<i>Symplocos racemosa</i> Roxb.	0.19	0.08	0.03	0.07	0.39	-	-	-	-	-	-	-	-	-	-
21	<i>Syzygium cumini</i> (L) Skeels	10.33	15.16	1.00	3.88	30.82	-	-	-	-	-	-	-	-	-	-
22	<i>Terminalia alata</i> Heyne exRoth	4.13	5.55	0.41	1.55	11.66	12.98	29.77	1.07	4.88	48.71	23.75	49.74	2.03	8.93	84.46
23	<i>Terminalia chebula</i> Retz	6.37	11.22	0.58	2.39	20.57	-	-	-	-	-	-	-	-	-	-
	Total	74.84	117.25	7.32	28.29	227.71	38.48	67.95	4.56	16.49	127.69	50.79	107.68	4.74	19.97	183.20

**Table 4.8: Litter biomass (t/ha) in various component on different sites.**

Litter Biomass(t/ha)	Least Disturbed Site	Moderately Disturbed Site	Highly Disturbed Site
Fresh leaf litter	2.38	2.35	1.41
Wood litter	0.70	0.16	1.03
Partially decomposed litter	0.47	0.95	0.31
Total	3.55	3.46	2.75

partially decomposed litter constitute about 67.04, 19.71 and 12.95 per cent, respectively of the total litter biomass.

#### **4.3.2 Moderately disturbed site:**

The total above ground biomass for moderately disturbed site (Table 4.7) was 110.99 t ha<sup>-1</sup> and 16.49 t ha<sup>-1</sup> was below ground biomass constituting about 127.69 t ha<sup>-1</sup> of total biomass of site. The distribution of biomass in the different components was 53.21 per cent in bole, 30.13 per cent in branch, 3.57 per cent in leaf and 12.91 per cent in root. The bole, branch, leaf and root constitute about 67.95 t ha<sup>-1</sup>, 38.48 t ha<sup>-1</sup>, 4.56 t ha<sup>-1</sup> and 16.49 t ha<sup>-1</sup> biomass, respectively of the total biomass. Among the individual species *Terminalia alata* constituted the highest biomass (48.71) followed by *Lannea coromandelica* (17.75) and *Anogeissus latifolia* (17.25) which constitute about 38.14, 13.9 and 13.50 per cent of the total biomass.

The total litter biomass was 3.46 t ha<sup>-1</sup> (Table 4.8). The distribution of biomass in the different components was 2.35 t ha<sup>-1</sup> in fresh leaf litter, 0.16 t ha<sup>-1</sup> in wood litter and 0.96 t ha<sup>-1</sup> in partially decomposed litter (Fig. 4.12). The fresh leaf litter, wood litter and partially decomposed litter constitute about 67.80, 4.54 and 27.64 per cent, respectively of the total litter biomass.

#### **4.3.3 Highly disturbed site:**

The total biomass for highly disturbed site (Table 4.7) was 183.20 t ha<sup>-1</sup> of which 163.21 t ha<sup>-1</sup> was above ground and 19.97 t ha<sup>-1</sup> was below ground biomass. The distribution of biomass in the different components was 107.68 t ha<sup>-1</sup> in bole, 50.79 t ha<sup>-1</sup> in branch, 4.74 t ha<sup>-1</sup> in leaf and 19.97 t ha<sup>-1</sup> in root. The bole, branch, leaf and root biomass constitute about 58.77, 27.72, 2.58 and 10.90 per cent, respectively of the total

biomass. Among the individual species *Terminalia alata* constituted the highest biomass (84.46) followed by *Shorea robusta* (63.52) and *Lannea coromandelica* (13.77) which constitute about 46.10, 34.67 and 7.51 per cent of the total biomass.

The total litter biomass was 2.75 t ha<sup>-1</sup> (Table 4.8). The distribution of biomass in the different components was 1.41 t ha<sup>-1</sup> in fresh leaf litter, 1.03 t ha<sup>-1</sup> in wood litter and 0.13 t ha<sup>-1</sup> in partially decomposed litter (Fig. 4.12). The fresh leaf litter, wood litter and partially decomposed litter constitute about 51.27, 37.45 and 4.72 per cent, respectively of the total litter biomass. The present estimates are comparable with the estimates made by many workers. Cairns *et al.* (2003) have reported similar findings in tropical forest of Mexico and stated that the total above ground biomass was 225 Mg ha<sup>-1</sup>. Delaney *et al.* (1997) estimated 285 Mg ha<sup>-1</sup> above ground biomass for Venezuela Tropical moist forest.

In the present study above ground biomass is very similar to the above ground biomass calculated by Cairns *et al.* (2000) for the semi-evergreen tall/medium forest in the three states of the Yucatan Peninsula (111.2 Mg ha<sup>-1</sup>), but less than the above ground biomass for the state of Veracruz (225.8 Mg ha<sup>-1</sup>).

Brown *et al.* (1995) and Golley *et al.* (1975) estimated biomass of tropical moist forest and it was found that in the present study biomass was 34 per cent less than biomass estimates for Brazil tropical moist forest (306 Mg ha<sup>-1</sup>) and 57 per cent less than biomass of Panama tropical moist forest (358 Mg ha<sup>-1</sup>), respectively. Total below ground biomass of present study was between 16.49 t ha<sup>-1</sup> and 28.29 t ha<sup>-1</sup>, respectively which resembled with below ground biomass of tropical deciduous forest estimated by Singh *et al.* (2009).

**Table 4.9: Comparative account of stand biomass of certain tropical forests of the world (t ha<sup>-1</sup>)**

Forests	Location	Stand biomass			Source
		Above ground	Below ground	Total	
Tropical lower montane Rain	New Guinea	310	39	349	Edward and Grabb (1977)
Tropical wet	Cambodia	322	60	382	Hozumi <i>et al.</i> (1969)
Tropical wet	Global pattern	213-1173	11-135	269-1186	Murphy and Lugo (1986b)
Tropical Rain	Sarawak			210-650	Proctor <i>et al.</i> (1983b)
	India	420-649	14-20	434-669	Rai and Proctor (1986a)
	Thailand	295-371	31-33	326-404	Ogawa <i>et al.</i> (1965)
	Ghana	233	54	287	Greenland and Kowal (1960)
Tropical montane wet	Venezuela	347	73	420	Brun (1976)
Tropical Moist	San Carlos	340	56	396	Brunig <i>et al.</i> (1979)
		326	55	381	Folster <i>et al.</i> (1976)
	Global	316	11	327	Golley <i>et al.</i> (1975)
	Brazil Amazonia	377	104	481	Klinge and Herrera (1978)
	Ivory Coast	243	48	291	Muller and Nielson (1965)
Tropical Plantations	Puerto Rica	-	-	0.4-506	Lugo <i>et al.</i> (1988)
Tropical premontane Moist	Papua-New Guinea	286	46	332	Enright (1979)
	Zaire	320	51	371	Freson <i>et al.</i> (1974)
	Ivory Coast	431	24	455	Huttel and Bernhard-Reversat (1975)
Sub-tropical lower montane wet	Jamaica	279	65	344	Tanner (1980)
Sub-tropical wet	Eleverde Puerto Rico	237	116	353	Crow (1980)
	Global pattern	228	89	317	Jordan (1971a)
		198	73	271	Odum (1970)
Sub-tropical Moist	Thailand	253	10	263	Drew <i>et al.</i> (1978)
Sub-tropical Dry	Senegal	82	58	140	Jung (1969)
	Thailand	69	10	79	Ogawa <i>et al.</i> (1965)
	India	28	12	40	Vyas <i>et al.</i> (1977)
	Puerto Rico Guanica	53	45	98	Murphy and Lugo (1986a)
Tropical Dry	Global pattern	3-273	10-45	78-320	Murphy and Lugo (1986b)
	India	77	20	97	Singh and Mishra (1979)
Tropical moist	India	42-78	9-16	53-94	Singh and Singh (1991)
	India	110-199	16-28	127-227	Present study

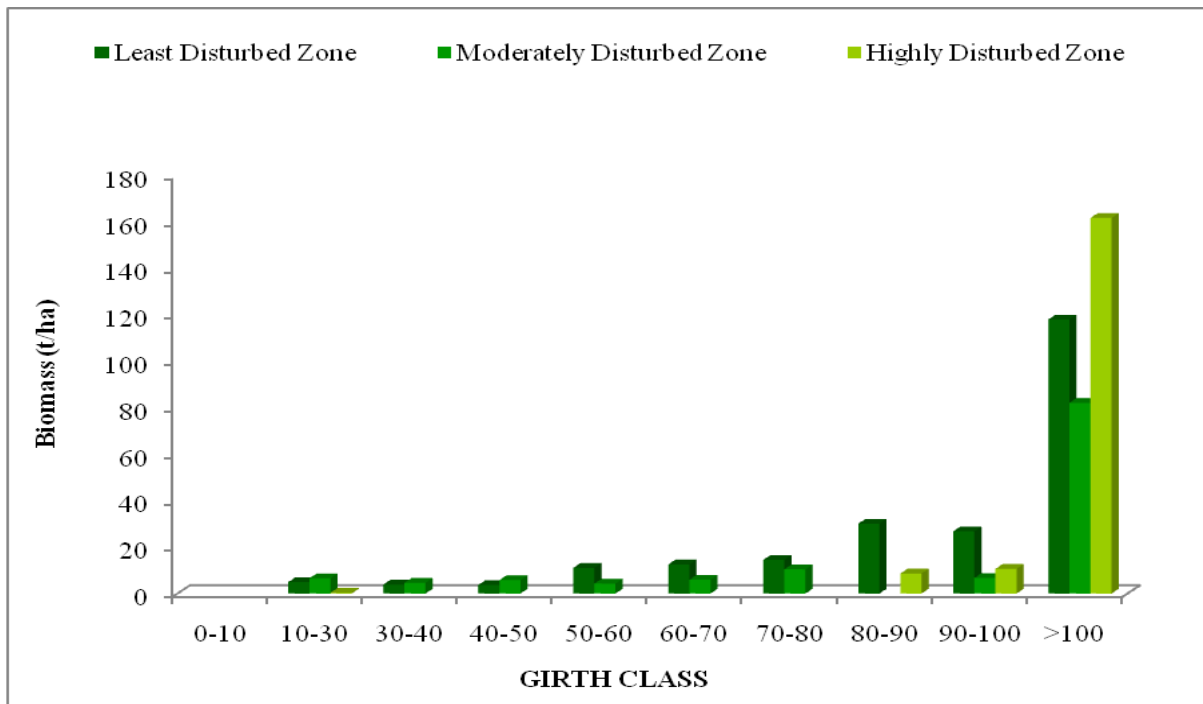
Hall and Uhling (1991) estimated the biomass density of forests in South and South East Asia using the volume estimates and biomass expansion factors derived from Brown *et al.* (1989). Their biomass estimates for India ranged from 116 Mg ha<sup>-1</sup> for undisturbed forest for 60-80 years and 35, 66 and 84 Mg ha<sup>-1</sup> for logged, unproductive and managed forests, respectively. However, the present estimates were comparable to Murphy and Lugo, 1986 (Table 4.9), where they reported 30 to 276 Mg ha<sup>-1</sup> above ground biomass for variety of dry tropical forests of the world. Tiwari (1994) reported average total above ground biomass in different forest types of Rajaji National Park, Dehradun, India between 52.36 t ha<sup>-1</sup> (Plantations) and 371.08 t ha<sup>-1</sup> (sal forest).

#### **Distribution pattern of biomass on three different forest sites:**

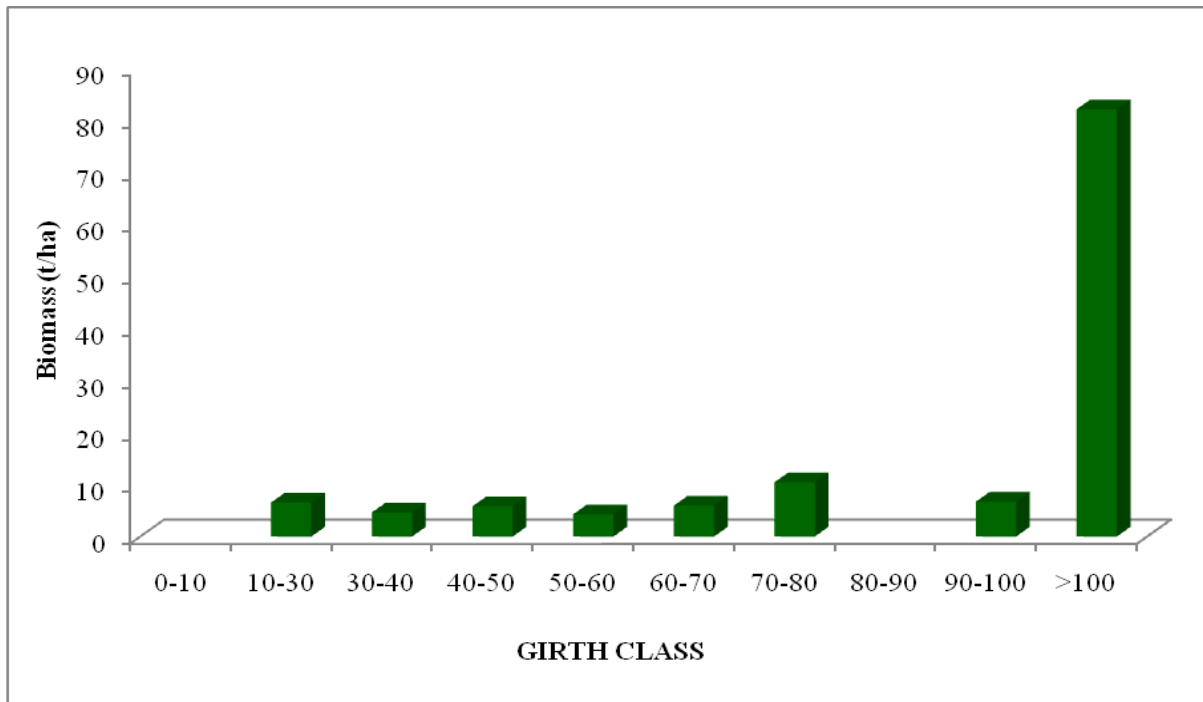
Although the young individuals belonging to seedlings and saplings classes dominated all the three site in terms of density but the total biomass accumulation was greater in the >100 cm girth class (Fig. 4.7).

In least disturbed site the total biomass accumulation was greater in the >100 cm girth class followed by middle girth class while it was minimum in smaller girth classes (Fig. 4.8). About 52.33 per cent biomass accumulation was in the girth class >100 cm, 37.22 per cent in girth class 60 -100 cm, 8.24 per cent in girth class 30-60 cm and 2.18 per cent in smaller girth class 10-30 cm.

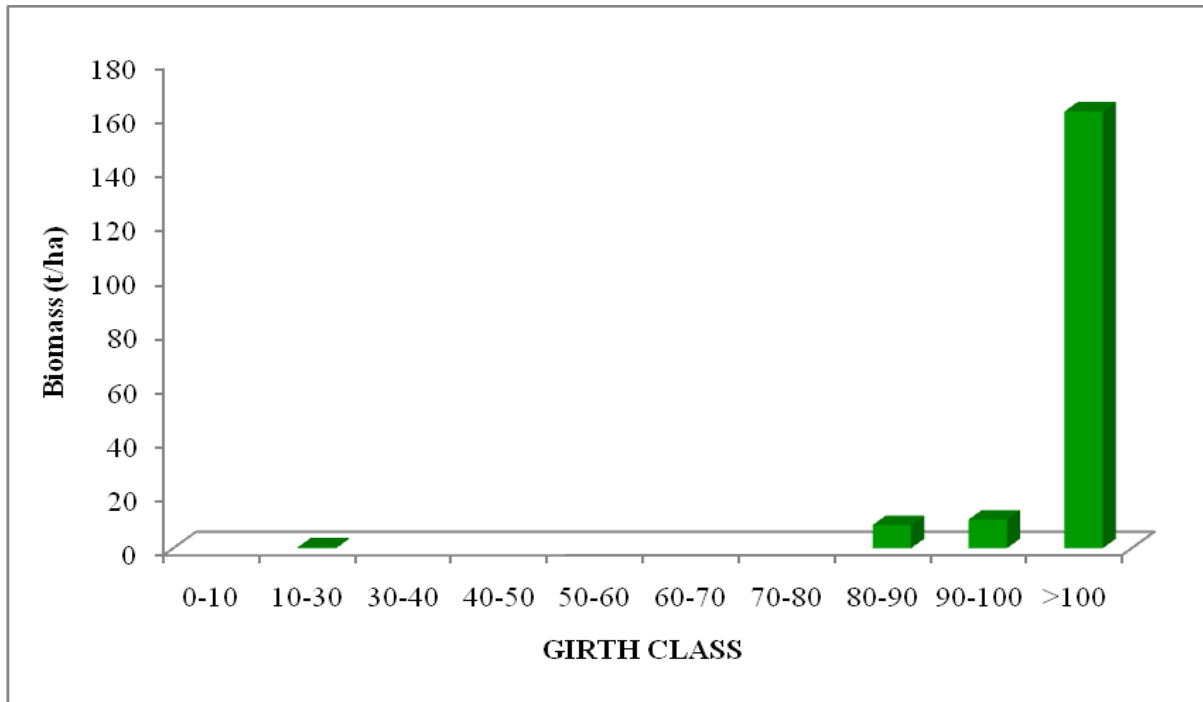
In moderately disturbed site the total biomass accumulation was greater in the >100 cm girth class followed by middle girth class while it was minimum in smaller girth classes (Fig. 4.9). About 64.95 per cent biomass accumulation was in the girth class >100 cm, 18.24 per cent in girth class 60-100 cm, 11.62 per cent in girth class 30-60 cm and 5.17 per cent in smaller girth class 10-30 cm.



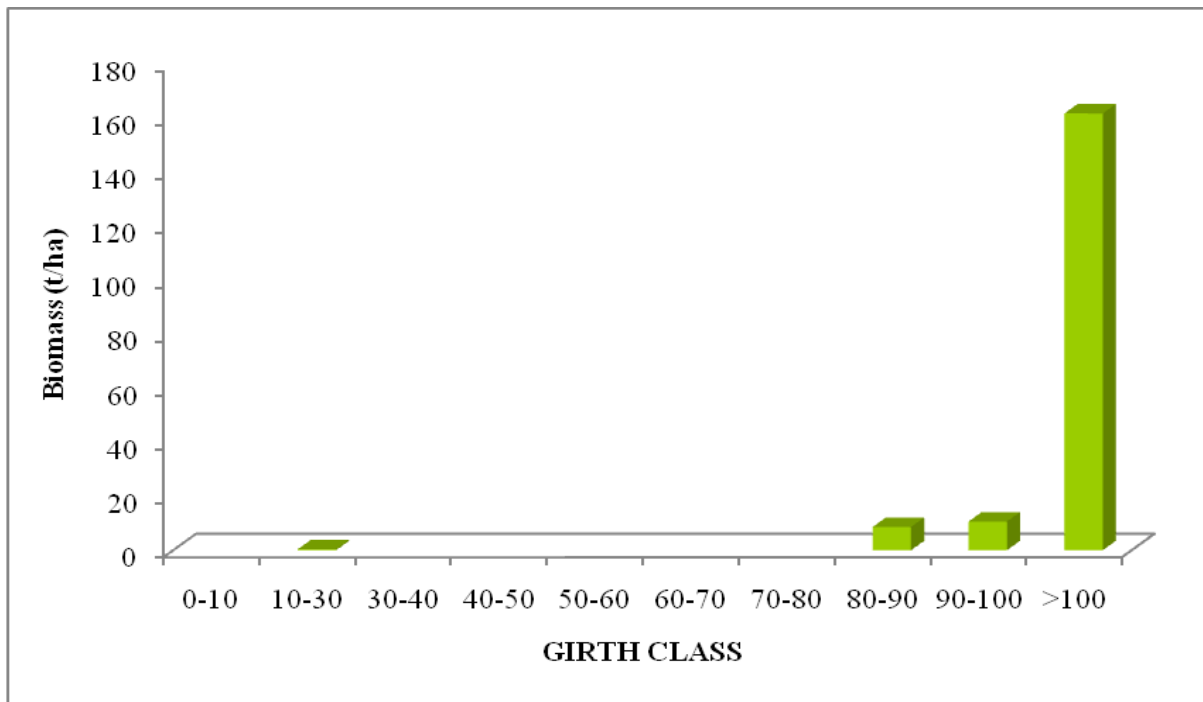
**Fig. 4.7: Distribution pattern of biomass along the girth classes on three different sites**



**Fig. 4.8: Distribution pattern of biomass along the girth classes in least disturbed site.**



**Fig. 4.9: Distribution pattern of biomass along the girth classes in moderately disturbed site.**



**Fig. 4.10: Distribution pattern of biomass along the girth classes in highly disturbed site.**

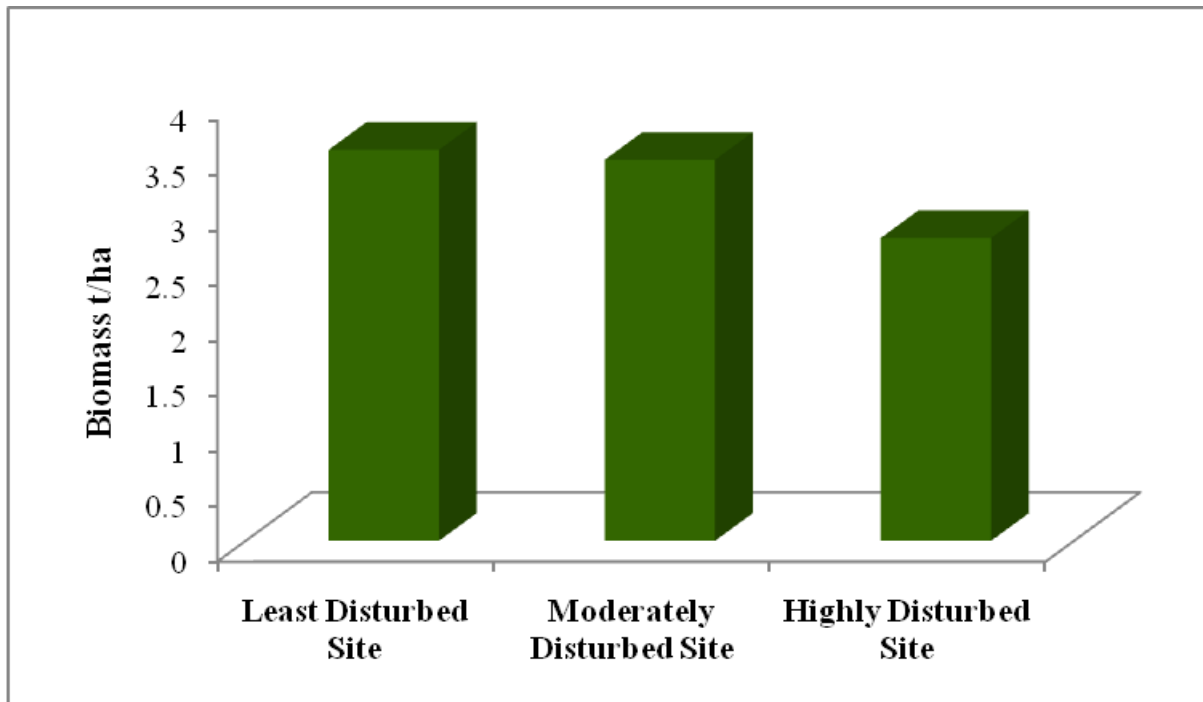


Fig. 4.11: Distribution pattern of litter biomass on different sites.

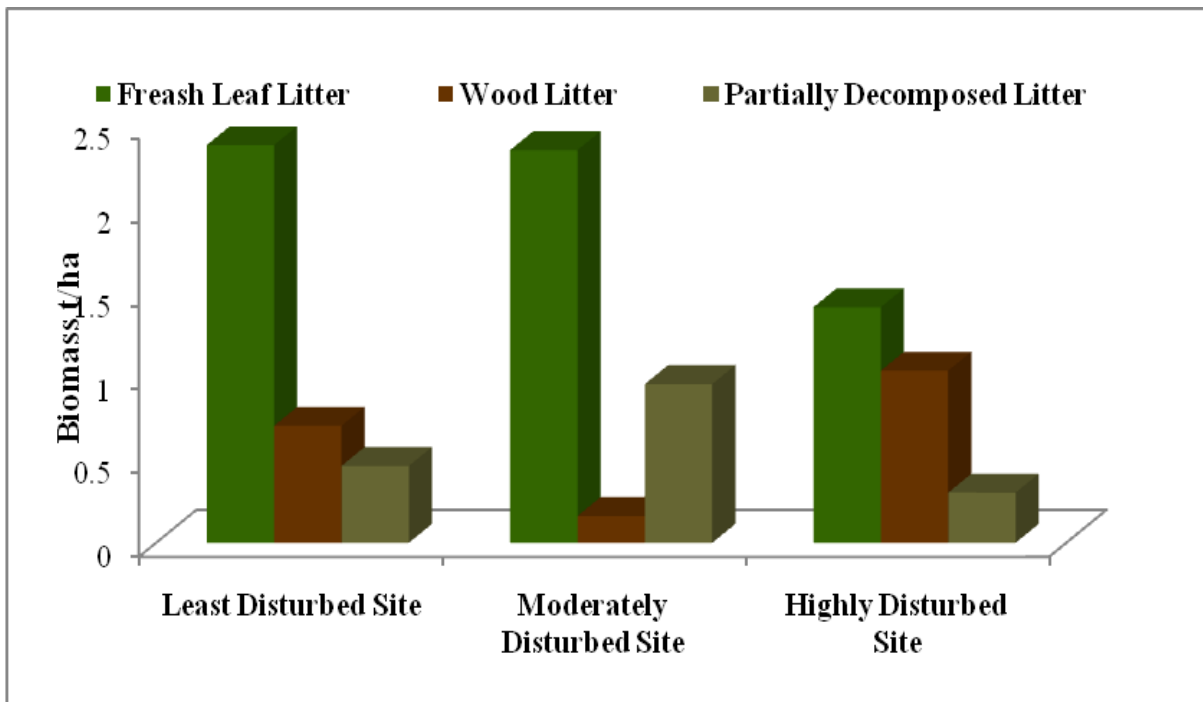


Fig. 4.12: Distribution pattern of litter biomass in various components on different sites.

In highly disturbed site the total biomass accumulation was greater in the >100 cm girth class while it was minimum in middle girth classes (Fig. 4.10). About 89.17 per cent biomass accumulation was in the girth class >100 cm, 10.62 per cent in girth class 60-100 cm and 0.19 per cent in smaller girth class 10-30 cm.

Total biomass accumulation in the >100 cm girth class was greater at highly disturbed site followed by least disturbed and moderately disturbed site. While in 60-100 cm girth class was greater at least disturbed site followed by moderately disturbed and minimum at highly disturbed site. In 30-60 cm girth class greater at moderately disturbed site followed by least disturbed site and in 10-30 cm girth class greater at moderately disturbed site followed by least disturbed and highly disturbed site (Fig. 4.7).

#### **4.4 Correlation and regression relationship of altitude and lopping intensity with density, basal area and biomass**

The correlation analysis indicates that there was a positive influence of altitude whereas, negative influence of lopping intensity on density, basal area and biomass. There was a strong positive influence of altitude on seedling density ( $r = 0.7641$ ), sapling density ( $r = 0.6396$ ) and tree density ( $r = 0.7195$ ) while there was negative influence of lopping intensity on seedling density ( $r = -0.6921$ ), sapling density ( $r = -0.4979$ ) and tree density ( $r = -0.7696$ ) at 1% levels of significance.

The correlation analysis for basal area indicates that there was a positive correlation ( $r = 0.3780$ ) between basal area and altitude while, there was negative correlation ( $r = -0.3839$ ) between basal area and lopping intensity at 5% levels of significance. It was found that biomass was not significantly correlated with ( $r = 0.114$ ) altitude and ( $r = -0.0919$ ) lopping intensity.

**Table no. 4.10: Effect of altitude and lopping intensity on plant density, basal area & biomass.**

Y \ X	ATTITUDE (m)			LOPPING INTENSITY [%]		
	a	b	r	a	b	r
Seedling Density (plants/ha)	-6109**	14.55**	0.7641**	4288**	-36.08**	-0.6921**
Sapling Density (plants/ha)	-105.0**	0.242**	0.6396**	64.150**	-0.517**	-0.4979**
Tree Density (stems/ha)	-81.88**	0.1915**	0.7197**	59.359**	-0.560**	-0.7696**
Basal area (m <sup>2</sup> /ha)	-1.068 <sup>NS</sup>	0.0048**	0.3780*	2.439**	-0.013*	-0.3839*
Biomass (t/ha)	9.859 <sup>NS</sup>	0.013 <sup>NS</sup>	0.114 <sup>NS</sup>	19.543**	-0.031**	-0.0919 <sup>NS</sup>

Note: - \*\* Significant at  $p \leq 0.01$

\* Significant at  $p \leq 0.05$

NS Non significant

x = Independent variable

y = Dependent variable

a = intercept

b = Regression coefficient

r = Correlation coefficient

Regression line indicates that with 1 m increase in altitude the density, basal area and biomass get increased while with 1% increase in logging intensity the density, basal area and biomass get decreased (Table 4.10).

#### **4.5 Effect of protection on physicochemical properties of soil**

The physico-chemical properties of soil in different forest sites viz., least disturbed site, moderately disturbed site and highly disturbed site was given in Table 4.11. Available nitrogen observed under soil of different study sites were ranged from 0.078 to 0.081 for surface soil sample (0-10 cm) and 0.028 to 0.073 for lower layer soil sample (10-20 cm). Among the disturbed sites, the highly disturbed sites contained maximum nitrogen content as compare to the other sites.

The organic carbon content in soil of least disturbed site was 1.443% and 0.617% for surface soil and lower layer soil sample which revealed lowest per cent of organic carbon as compare to the other sites of the study area. Soil under moderately disturbed site and highly disturbed site revealed little variation in organic carbon which varied from 1.497 to 1.638 %, respectively.

The concentration of soil phosphorus (0-20 cm) under the least disturbed site and moderately disturbed site varied from 5.46 to 7.16 kg ha<sup>-1</sup> and 14.45 to 14.48 kg ha<sup>-1</sup>, respectively (Table 4.11). The availability of phosphorus (0-20 cm) in the soil of highly disturbed site was found to be higher as 28.88 kg ha<sup>-1</sup> to 35.57 kg ha<sup>-1</sup> than the other disturbed sites. Whereas it was recorded minimum in the least disturbed site.

The result of available potassium for the soil depth 0-20 cm were 283.76 to 322.56 kg ha<sup>-1</sup>, 323.49 to 322.26 kg ha<sup>-1</sup> and 369.03 to 322.52 kg ha<sup>-1</sup> under least, moderately and highly disturbed sites, respectively. In all the study sites the potassium

**Table 4.11: Physico-Chemical properties of soil on different sites**

Soil physico-chemical properties	Least disturbed site				Moderately disturbed site				Highly disturbed site			
	(0-10) cm		(10-20) cm		(0-10) cm		(10-20) cm		(0-10) cm		(10-20) cm	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
<b>N%</b>	0.078	-	0.028	-	0.079	-	0.073		0.081	-	0.068	-
<b>C%</b>	1.443	-	0.617	-	1.522	-	1.537		1.638	-	1.497	-
<b>P (Kg/ha)</b>	5.46	2.34	7.16	2.16	14.45	0.87	14.48	0.70	28.88	3.60	35.57	1.73
<b>K (Kg/ha)</b>	283.76	0.97	322.56	40.97	323.49	6.64	322.26	67.09	369.03	30.41	322.52	37.38
<b>pH</b>	5.67	0.08	5.40	0.10	5.77	0.05	5.43	0.05	5.34	0.11	5.35	0.06
<b>Sand%</b>	80.13	3.41	78.13	2.47	74.00	2.01	69.60	3.44	72.53	2.29	70.47	0.88
<b>Silt%</b>	6.73	2.89	6.53	1.44	10.67	0.85	11.27	3.51	9.60	1.45	10.80	1.20
<b>Clay%</b>	13.13	0.93	15.33	1.03	14.67	0.98	19.13	0.27	17.20	0.23	18.73	0.47
<b>Bulk density</b>	1.354	0.076	1.323	0.069	1.388	0.060	1.349	0.067	1.299	0.12	1.273	0.11

content was low in least disturbed site while it was higher under the soil of highly disturbed site.

The pH value (mean) of soil under least disturbed site was 5.67 and 5.40 in surface soil (0-10 cm) and lower layer (10-20 cm). Whereas it was recorded 5.77 (surface soil) and 5.43 (lower layer) for moderately and 5.34 (surface soil) and 5.35 (lower layer) for highly disturbed site, respectively.

The soil texture in the entire three sites was sand dominated which represent sandy loam soil texture of soil. The soil of least disturbed site contained 80.13% sand, 6.73% silt and 13.13% clay in surface soil sample (0-10 cm) whereas, it was recorded 78.13% sand, 6.53% silt and 15.13% clay in the sample taken from the depth of 10-20 cm. Soil under moderately disturbed site was comprised of 74% sand, 10.67% silt and 14.67% clay in surface soil sample (0-10 cm) whereas, it was recorded as 69.60% sand, 11.27% silt and 19.13% clay in lower soil layer sample (10-20 cm). The soil of highly disturbed site had less sand than the other site but higher clay mean value (Table 4.11).

The bulk density was  $1.345 \text{ g cm}^{-3}$  (surface layer) and  $1.323 \text{ g cm}^{-3}$  (lower layer) for least disturbed site. In moderately disturbed site it was recorded as  $1.388 \text{ g cm}^{-3}$  (surface layer) and  $1.349 \text{ g cm}^{-3}$  (lower layer). Whereas, it was  $1.299 \text{ g cm}^{-3}$  for surface layer and  $1.273 \text{ g cm}^{-3}$  for lower layer in highly disturbed site, respectively.

Soil function is a result of a complex combination of physical, chemical and biological processes which are played out in a structurally heterogeneous and materially complex environment (Coleman and Elliott, 1987). The soil organic matter contributes to the soil fertility in a number of ways. It increases cation exchange capacity, (Johnston, 1986) water holding capacity, (Salter and Williams, 1969) and availability of nutrients

(Schnitzer and Khan, 1978). Both quantity and quality of organic matter interact with soil micro climate and thus influence biogeochemical cycling particularly in relatively dry ecosystem (Burke, 1989) and functioning of this ecosystem.

In general, most microbial activity occurs in the upper soil layers (0-20 cm) as soil at this depth is more nutritious and porous. Burke (1989) suggested that nutrient accumulation is a dynamic ecosystem property and is influenced by slowly changing landscape pattern in semi-arid ecosystem; nutrient dynamics are closely linked to seasonal variation in temperature and moisture. Moreover, the higher values of mineral N, inorganic P and soil physical properties close to trees could be attributed to higher amount of organic matter inputs through litter fall, root mortality and herbaceous biomass.

Paul *et al.* (2003) reported the effect of topographic position on pH, concentration of total C, total N and extractable P. Singh *et al.* (2000) reported that temporal variation in soil organic carbon, increased soil organic carbon and coincided with the periods of litter production. Subsequent to deforestation, decomposition rates of organic matter, both on the soil surface and within the top soil layers, are enhanced, rendering the system vulnerable to leakage of nutrients (Bargali *et al.*, 1992).

*SUMMARY, CONCLUSION AND  
SUGGESTION FOR FUTURE  
RESEARCH WORK*

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## **CHAPTER-V**

### **SUMMARY CONCLUSION AND SUGGESTIONS FOR FUTURE WORK**

“A Study on the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest” was carried out at Katghora Forest Division under Bilaspur Circle of Korba district (Chhattisgarh) which is located between 21<sup>0</sup>20'00” and 21<sup>0</sup>25'47” North latitudes and 82<sup>0</sup>21'17” and 82<sup>0</sup>26'27” East longitudes having an area of 4187.371 km<sup>2</sup> during the year 2010-2011.

The Regeneration Status, Species Diversity, Structure and Biomass Pattern of different forest sites were measured by randomly placing quadrats of 10 m x 10 m at various sites. Randomly 10 quadrats were laid down in each forest sites. In each quadrat GBH (girth at breast height) of each adult individual ( $\geq 10$  cm gbh) were measured. In the center of each 10 m x 10 m quadrat, 2 m x 2 m quadrat area was marked for enumeration of seedling. The structural analysis was done by determining primary variables (frequency, density and basal area). Subsequently secondary variables (relative frequency, relative density, relative basal area and IVI) were computed from primary data. The diversity parameters viz., Shannon index, Simpson's Index, equitability, species richness and beta diversity were also calculated for each forest sites. Biomass for each forest sites was estimated using allometric equations based on the relationship between girth of a tree and dry weight of component. The salient findings on a Study on the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest were summarized below:

## Regeneration status

- The density of seedlings was found to be 39500 ha<sup>-1</sup> of 14 species at least disturbed site, 26000 ha<sup>-1</sup> of 8 species at moderately disturbed site and 7750 ha<sup>-1</sup> of 4 species at highly disturbed site.
- The density of sapling was found to be 490 ha<sup>-1</sup> of 9 species at least disturbed site, 610 ha<sup>-1</sup> of 9 species at moderately disturbed site and 30 ha<sup>-1</sup> of 2 species at highly disturbed site.
- In least disturbed site three species, viz., *Buchanania lanzan*, *Madhuca latifolia* and *Shorea robusta* showed good regeneration as all these species having good number of seedlings and saplings.
- In moderately disturbed site, four species showed good regeneration while two species recorded poor regeneration, three were not abundant and seven species were not found to be regenerating.
- The highly disturbed site was poor in regeneration for most of the species although, only *Lagerstroemia parviflora* showed good regeneration.

## Species structure

### Least disturbed site

- On least disturbed site *Shorea robusta* was recognized as dominant plant species and *Madhuca latifolia* as co-dominant.
- Maximum density was observed for *Shorea robusta* (170 stems ha<sup>-1</sup>) followed by *Madhuca latifolia* (130 stems ha<sup>-1</sup>) and *Syzygium cumini* (60 stems ha<sup>-1</sup>).
- Maximum basal cover was observed for *Shorea robusta* (11.47 m<sup>2</sup> ha<sup>-1</sup>) followed by *Syzygium cumini* (5.08 m<sup>2</sup> ha<sup>-1</sup>) and *Madhuca latifolia* (5.03 m<sup>2</sup> ha<sup>-1</sup>).

- Basal area and density of individual tree species varied from 0.11 m<sup>2</sup> ha<sup>-1</sup> to 11.47 m<sup>2</sup> ha<sup>-1</sup> and 10 to 170 stems ha<sup>-1</sup>, respectively.
- Highest IVI was observed for *Shorea robusta* (102.81) followed by *Madhuca latifolia* (67.91) and *Syzygium cumini* (39.66).
- The total density and basal area on least disturbed site was 510 trees ha<sup>-1</sup> and 26.67 m<sup>2</sup> ha<sup>-1</sup>.
- In the least disturbed site out of total trees 20.31 per cent trees were found to be lopped while 79.69 per cent trees found unlopped.

#### **Moderately disturbed site**

- On moderately disturbed site *Holarrhena pubescens* was recognized as dominant plant species and *Lagerstroemia parviflora* as co-dominant.
- Maximum density was observed for *Holarrhena pubescens* (100 stems ha<sup>-1</sup>) followed by *Lagerstroemia parviflora* (90 stems ha<sup>-1</sup>).
- Maximum basal cover was observed for *Terminalia alata* (3.36 m<sup>2</sup> ha<sup>-1</sup>) followed by *Lannea coromandelica* (1.73 m<sup>2</sup> ha<sup>-1</sup>) and *Holarrhena pubescens* (1.64 m<sup>2</sup> ha<sup>-1</sup>).
- Basal area and density of individual tree species varied from 0.09 m<sup>2</sup> ha<sup>-1</sup> to 3.36 m<sup>2</sup> ha<sup>-1</sup> and 10 to 100 stems ha<sup>-1</sup>, respectively.
- Highest IVI was observed for *Holarrhena pubescens* (74.62) followed by *Lagerstroemia parviflora* (65.64) and *Terminalia alata* (43.83).
- The total density and basal area on moderately disturbed site was 310 trees ha<sup>-1</sup> and 11.46 m<sup>2</sup> ha<sup>-1</sup>.
- In the moderately disturbed site out of total trees 44.64 per cent trees were found to be lopped while 55.36 per cent trees found unlopped.

### **Highly disturbed site**

- On highly disturbed site *Terminalia alata* emerged as dominant plant species and *Shorea robusta* as co-dominant.
- Maximum density was observed for *Terminalia alata* (40 stems ha<sup>-1</sup>) followed by *Shorea robusta* (20 stems ha<sup>-1</sup>).
- Maximum basal cover was observed for *Terminalia alata* (6.70 m<sup>2</sup> ha<sup>-1</sup>) followed by *Shorea robusta* (4.73 m<sup>2</sup> ha<sup>-1</sup>) and *Lannea coromandelica* (1.38 m<sup>2</sup> ha<sup>-1</sup>).
- Basal area and density of individual tree species varied between 0.55 m<sup>2</sup> ha<sup>-1</sup> to 6.70 m<sup>2</sup> ha<sup>-1</sup> and 10 to 40 stems ha<sup>-1</sup>, respectively.
- Highest IVI was recorded for *Terminalia alata* (125.67) followed by *Shorea robusta* (72.25) and *Lannea coromandelica* (29.07).
- The total density and basal area on highly disturbed site was 100 trees ha<sup>-1</sup> and 14.67 m<sup>2</sup> ha<sup>-1</sup>.
- In the highly disturbed site out of total trees 92.48 per cent trees were found to be lopped while 7.52 per cent trees found unlopped.

### **Species diversity**

- Species richness in various forest plots ranged from 1.08 to 1.91 and recorded highest on moderately disturbed site (1.91) and lowest on highly disturbed site (1.08).
- Shannon index in forest plots under study ranged between 2.32 to 2.83. It was highest on moderately disturbed site (2.83) and lowest on highly disturbed site (2.32).
- Concentration of dominance ranged between 0.20 to 0.24, being highest on highly disturbed site (0.24).

- Equitability (e) values ranged from 1.13 to 1.29, respectively in various forest plots and was highest on highly disturbed site and lowest on moderately disturbed site.
- Beta diversity values in various forest plots ranged from 1.50 to 3.00 and was highest on highly disturbed site (3.00) and lowest on moderately disturbed site (1.50).

## **Biomass**

### **Least disturbed site**

- The total biomass on least disturbed site was 227.71 t ha<sup>-1</sup> of which 199.41 t ha<sup>-1</sup> was above ground and 28.29 t ha<sup>-1</sup> was below ground .
- *Shorea robusta* constituted the highest biomass (110.31 t ha<sup>-1</sup>) followed by *Madhuca latifolia* (43.70 t ha<sup>-1</sup>) and *Syzygium cumini* (30.82 t ha<sup>-1</sup>).
- The distribution of biomass in the different components was 117.25 t ha<sup>-1</sup> in bole, 74.84 t ha<sup>-1</sup> in branch, 7.32 t ha<sup>-1</sup> in leaf and 28.29 t ha<sup>-1</sup> in root.
- The bole, branch, leaf and root constituted 51.49, 32.86, 3.21 and 12.42 per cent of the total biomass, respectively.
- The total litter biomass estimated was 3.55 t ha<sup>-1</sup>.
- The distribution of litter biomass in the different components was 2.38 t ha<sup>-1</sup> in fresh leaf litter, 0.70 t ha<sup>-1</sup> in wood litter and 0.46 t ha<sup>-1</sup> in partially decomposed litter.

### **Moderately disturbed site**

- The total above ground biomass on moderately disturbed site was 110.99 t ha<sup>-1</sup> and 16.49 t ha<sup>-1</sup> was below ground biomass constituting about 127.69 t ha<sup>-1</sup> as total biomass of site.

- *Terminalia alata* constituted the highest biomass (48.71 t ha<sup>-1</sup>) followed by *Lannea coromandelica* (17.75 t ha<sup>-1</sup>) and *Anogeissus latifolia* (17.25 t ha<sup>-1</sup>).
- The distribution of biomass in the different components was 53.21 per cent in bole, 30.13 per cent in branch, 3.57 per cent in leaf and 12.91 per cent in root.
- The bole, branch, leaf and root constituted 67.95 t ha<sup>-1</sup>, 38.48 t ha<sup>-1</sup>, 4.56 t ha<sup>-1</sup> and 16.49 t ha<sup>-1</sup> biomass, respectively of the total biomass.
- The total litter biomass estimated was 3.46 t ha<sup>-1</sup>.
- The fresh leaf litter, wood litter and partially decomposed litter constituted 67.80, 4.54 and 27.64 per cent, respectively of the total litter biomass.

#### **Highly disturbed site**

- The total biomass on highly disturbed site was 183.20 t ha<sup>-1</sup> of which 163.21 t ha<sup>-1</sup> was above ground and 19.97 t ha<sup>-1</sup> was below ground biomass.
- *Terminalia alata* constituted the highest biomass (84.46) followed by *Shorea robusta* (63.52) and *Lannea coromandelica* (13.77).
- The distribution of biomass in the different components was 107.68 t ha<sup>-1</sup> in bole, 50.79 t ha<sup>-1</sup> in branch, 4.74 t ha<sup>-1</sup> in leaf and 19.97 t ha<sup>-1</sup> in root.
- The bole, branch, leaf and root biomass constituted 58.77, 27.72, 2.58 and 10.90 per cent, respectively of the total biomass.
- The total litter biomass estimated was 2.75 t ha<sup>-1</sup>.
- The distribution of litter biomass in the different components was 1.41 t ha<sup>-1</sup> in fresh leaf litter, 1.03 t ha<sup>-1</sup> in wood litter and 0.13 t ha<sup>-1</sup> in partially decomposed litter.

## Physico-Chemical properties of Soil

- The pH of the (0-10 cm) surface soil in the site ranged from 5.34 for highly disturbed site to 5.77 for moderately disturbed site Whereas of lower layer (10-20 cm) ranged from 5.35 for highly disturbed site to 5.43 for moderately disturbed site .
- The surface soil (0-10 cm) of least disturbed site contained 80.13% sand, 6.73% silt and 13.13% clay, whereas moderately disturbed site was comprised of 74% sand, 10.67% silt and 14.67% of clay. The soil of highly disturbed site had less sand than the other site but higher clay content.
- The bulk density of soil on surface layer ranged from 1.299 g cm<sup>-3</sup> and 1.388 g cm<sup>-3</sup> and on lower layer ranged from 1.273 g cm<sup>-3</sup> and 1.349 g cm<sup>-3</sup>, respectively.
- The organic carbon content in soil of least disturbed site was 1.443% and 0.617% for surface soil and lower layer soil. In moderately disturbed site and highly disturbed site organic carbon content varied from 1.497 to 1.638 %, respectively.
- The highly disturbed sites contained maximum nitrogen content as compare to the other sites. It ranged from 0.078 to 0.081 for surface soil sample (0-10 cm) and 0.028 to 0.073 for lower layer soil sample (10-20 cm) in all three sites.
- The concentration of soil phosphorus (0-20 cm) was 5.46 to 7.16 kg ha<sup>-1</sup> in least disturbed site, 14.45 to 14.48 kg ha<sup>-1</sup> on moderately disturbed site and 28.88 kg ha<sup>-1</sup> to 35.57 kg ha<sup>-1</sup> on highly disturbed site.
- Available potassium for the soil depth 0-20 cm were 283.76 to 322.56 kg ha<sup>-1</sup>, 323.49 to 322.26 kg ha<sup>-1</sup> and 369.03 to 322.52 kg ha<sup>-1</sup> under least, moderately and highly disturbed site, respectively.

## **Conclusion and suggestions for future work**

The present study reveals that the high level of disturbance due to overexploitation of trees for timber and firewood had critically affected the regeneration status, species structure, diversity and biomass of the forest. This is evidenced by the very low density, diversity and basal area on highly disturbed site. The forest has lost its climax vegetation due to anthropogenic pressure which if increased, may retrogress the succession into a degraded community.

Despite the escalating exploitation of the forest, the phytosociological analysis indicates that this forest is an extremely important ecosystem by the virtue of high richness and diversity of tree species. In addition the presence of a large number of seedlings of woody species in the forest indicates the great potential source for sustainable future regeneration of the forest, provided that appropriate management regimes can be employed. Hence, these forests have a tremendous potential if they are conserved and used sustainably.

Therefore, study suggests that protection measures are needed to protect the forest from degradation and conserve the biodiversity. In order to encourage and improve regeneration in forests, the temporary closure of degraded site needs to be made at least for a period of 5 to 10 years. Major strategies needed for biodiversity conservation are reduction of pressure on resources, rehabilitation of sensitive species, restoration of degraded site and sustainable extraction of fuelwood and small timber from forest.

It is also suggested to practice alternate system of land management/agri-silvicultural practices in marginal, degraded and agricultural lands, which are actually underutilized. These strategies will help in reducing the biotic pressure and conserving the fragile tropical deciduous forests of Chhattisgarh. Various

management strategies has to be meticulously and scientifically planned involving various experts from various fields and organizations including local community. Involvement of local community in conservation of forest is essential as they heavily depend on forest for various resources. Thus, it would be possible to conserve and use the resources in a sustainable way if local communities start believing and understanding the concept of ecosystem conservation.

*ABSTRACT*

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**“A Study on the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest”**

**By**

**PAWAR GEETA**

**ABSTRACT**

The present work aimed to study the Effect of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest during 2010-2011. Regeneration status of forest was determined based on population size of seedlings and saplings. Forest structure was determined using phytosociological observations. Biomass for each site was estimated using allometric equations based on the relationship between girth of tree and dry weight of the components (bole, branch, leaf & root).

A total of 27 species of 19 families were encountered. Regeneration status in all the study sites are dissimilar. Although least disturbed site was regenerating well with *Shorea robusta* and *Diospyros melanoxylon*. Tree stand density varied from 100-510 stems ha<sup>-1</sup> with basal area ranging from 11.46 to 26.67 m<sup>2</sup> ha<sup>-1</sup>. Species diversity index varied between 2.32 for highly disturbed site to 2.83 for moderately disturbed site, Simpson index of diversity ranged between 0.20 and 0.24. The Margalef 's index of richness varied from 1.08-1.91, Equatibility index varied from 1.13 to 1.29 and  $\beta$  diversity varied from 1.50 to 3.00.

Total biomass (t ha<sup>-1</sup>) was maximum in Least disturbed site (227.71) followed by Highly disturbed site (183.20) and Moderately disturbed site (127.69). In Least disturbed site *Shorea robusta* constituted the highest biomass while in Moderately disturbed site and Highly disturbed site *Terminalia alata* constituted the highest biomass.

From these studies it is evident that least disturbed site has an edge over moderately and highly disturbed site in terms of regeneration, species diversity, dominance, richness and biomass accumulation. Efforts are needed to conserve the forest for their diversity and existence.

**Date:**  
**Place: Raipur**

**Dr. Lalji Singh**  
**Chairman**  
**Advisory committee**

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## *APPENDIX*

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## APPENDIX

**Appendix-I: Allometric relationship between the log dry weight (kg) of different components (Y) on log girth ( X, cm) for trees in natural forests (Based on Singh, K.P. and Misra , R. 1979). All equations are of the form  $\text{Log } Y = a + b \log X$ .**

Species	component	Correlation coefficient r	intercept log <u>a</u>	slope <u>b</u>	Standard error of estimate (SEE)	Standard error of b (SE of b)
<i>Anogeissus latifolia</i> (n=23)	Bole	0.9977	-1.8132	2.0630	0.0346	0.0304
	Branch	0.9970	-2.4915	2.6983	0.0523	0.0460
	Leaf	0.9798	-3.2713	2.4708	0.1251	0.1100
	Root	0.9938	-2.3785	2.2849	0.0635	0.0558
	Total	0.9979	-1.8287	2.4177	0.0391	0.0344
<i>Diospyros melanoxylon</i> (n=21)	Bole	0.9961	-2.3639	2.4012	0.0498	0.0486
	Branch	0.9941	-3.7528	3.1466	0.0805	0.0785
	Leaf	0.9678	-2.7088	1.9890	0.1217	0.1186
	Root	0.9923	-2.5205	2.2442	0.0659	0.0643
	Total	0.9988	-2.2359	2.5331	0.0289	0.0282
<i>Buchanania lanzan</i> (n=24)	Bole	0.9957	-2.3043	2.3252	0.0567	0.0459
	Branch	0.9929	-4.6363	3.6077	0.1140	0.0923
	Leaf	0.9858	-2.9857	2.2339	0.1000	0.0810
	Root	0.9976	-2.6984	2.2529	0.0413	0.0334
	Total	0.9952	-2.4411	2.6143	0.0679	0.0549
<i>Pterocarpus marsupium</i> (n=21)	Bole	0.9937	-2.1871	2.3169	0.0632	0.0597
	Branch	0.9936	-3.3958	2.9497	0.0814	0.0769
	Leaf	0.9916	-2.3706	1.7609	0.0558	0.0527
	Root	0.9754	-2.9550	2.4184	0.1326	0.1253
	Total	0.9969	-2.1540	2.4860	0.0474	0.0448
<i>Phyllanthus emblica</i> (n=21)	Bole	0.9970	-2.2675	2.3179	0.0436	0.0415
	Branch	0.9914	-3.1576	2.8571	0.0910	0.0867
	Leaf	0.9910	-2.2645	1.7667	0.0574	0.0547
	Root	0.9964	-2.1898	2.0283	0.0417	0.0397
	Total	0.9987	-2.0281	2.4227	0.0297	0.0283
<i>Flaourtia ramontchi</i> (n=15)	Bole	0.9850	-2.0747	2.2774	0.0818	0.1106
	Branch	0.9939	-2.7468	2.7141	0.0617	0.0833
	Leaf	0.9902	-2.6635	2.0118	0.0583	0.0788
	Root	0.9898	-2.5309	2.2709	0.0671	0.0907
	Total	0.9940	-1.9179	2.4300	0.0548	0.0740

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<i>Lagerstroemia parviflora</i> (n=18)	Bole	0.9957	-2.2277	2.2908	0.0492	0.0534
	Branch	0.9898	-2.9451	2.6849	0.0888	0.0964
	Leaf	0.9853	-2.7657	2.0988	0.0840	0.0911
	Root	0.9920	-3.0475	2.5876	0.0758	0.0822
	Total	0.9965	-2.0908	2.4470	0.0472	0.0512
<i>Saccupetalum tomentosum</i> (n=24)	Bole	0.9933	-2.4161	2.5060	0.0657	0.0810
	Branch	0.9937	-3.9360	3.2905	0.0838	0.1033
	Leaf	0.9936	-2.7398	2.0922	0.0536	0.0660
	Root	0.9957	-3.1304	2.6249	0.0549	0.0676
	Total	0.9972	-2.4028	2.6826	0.0456	0.0561
<i>Grewia tiliaefolia</i> (n=18)	Bole	0.9925	-2.4946	2.4910	0.0723	0.0768
	Branch	0.9661	-2.7396	2.6410	0.1660	0.1764
	Leaf	0.9910	-2.3512	1.8503	0.0590	0.0626
	Root	0.9977	-2.6802	2.3433	0.0371	0.0394
	Total	0.9893	-2.0260	2.4495	0.0852	0.0905
<i>Eriolaena hookeriana</i> (n=12)	Bole	0.9932	-2.8174	2.7104	0.0579	0.1004
	Branch	0.9880	-3.4809	3.1303	0.0893	0.1548
	Leaf	0.9927	-2.3127	1.7989	0.0400	0.0693
	Root	0.9855	-2.8021	2.4096	0.0758	0.1314
	Total	0.9969	-2.4665	2.7390	0.0395	0.0685
<i>Acacia catechu</i> (n=12)	Bole	0.9938	-2.0973	2.3131	0.0508	0.0819
	Branch	0.9906	-3.1626	2.9565	0.0800	0.1290
	Leaf	0.9822	-2.2882	1.6889	0.0634	0.1022
	Root	0.9920	-2.1735	2.0756	0.0518	0.0835
	Total	0.9949	-1.9235	2.4333	0.0482	0.0777
'Other species' (Total of all species) (n=200)	Bole	0.9874	-2.1725	2.2880	0.0842	0.0260
	Branch	0.9569	-3.2888	2.9420	0.2051	0.0635
	Leaf	0.9678	-2.6977	2.0403	0.1219	0.0377
	Root	0.9697	-2.0645	2.2913	0.1327	0.0410
	Total	0.9844	-2.0854	2.4750	0.1015	0.0314
<i>Tectona grandis</i> (n=15)	Bole	0.9950	-2.3687	2.3636	0.0520	
	Branch	0.9900	-3.2713	2.6579	0.0850	
	Leaf	0.9960	-2.8054	2.2401	0.0430	
	Root	0.9540	-2.2276	2.0172	0.1450	
	Total	0.9940	-1.9663	2.3001	0.0560	

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n = no. of trees felled.